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TRW Systems Group

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HAZARDOUS WASTE DISPOSAL PROGRAM

NINTH MONTHLY REPORT

CONTRACT 68-03-0089

Prepared for
the
Environmental Protection Agency

9 October 1972

TRW
SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

HAZARDOUS WASTE DISPOSAL PROGRAM

NINTH MONTHLY REPORT

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1. INTRODUCTION

Under the requirements of Section 212 of Public Law 91-512, The Office of Solid Waste Programs of the Environmental Protection Agency is in part required to prepare "a comprehensive report and plan for the creation of a system of national disposal sites for the storage and disposal of hazardous wastes, including radioactive, toxic chemical, biological, and other wastes which may endanger public health or welfare. Such a report shall include: 1) a list of materials which should be subject to disposal in any such site; 2) current methods of disposal of such materials; 3) recommended methods of reduction, neutralization, recovery, or disposal of such materials.

Contract 68-03-0089 is the second in a series of EPA projects which are designed to provide the information required in the report to Congress. The principal objective of the current program is to define and evaluate the waste management techniques and policies currently utilized for a specified set of hazardous wastes. Waste management techniques which will be evaluated include those for storage, handling, transport, neutralization, detoxification, reuse, and disposal. Other aspects of the program include description of possible new techniques for management of hazardous wastes, proof-of-principal experimentation to determine the effectiveness of techniques for which insufficient data is available for adequate evaluation, and planning of research programs necessary for developing new procedures and processes for treating hazardous wastes for which adequate techniques do not currently exist.

The ninth monthly technical report summarizes the work performed by TRW for EPA from September 1, 1972 to September 30, 1972 under Contract 68-03-0089.

2. PROGRAM ACCOMPLISHMENTS

The program is divided into seven major tasks consisting of:

- Defining Adequate Waste management. Toxicity information and toxicological standards on each hazardous material contained in lists supplied by the Solid Waste Research Office will be reviewed. Other factors (such as flammability or explosive potential) which affect the waste management process will be investigated where applicable. Acceptable criteria in terms of impact on mankind and the environment for each of the waste management steps (handling, storage, transportation, disposal, etc.) shall be defined.
- Evaluating Presently Employed Waste Management Techniques or Policies and Making Recommendations as to Adequacy. The existing techniques for waste management of each hazardous material (supplied as in Task 1) will be assessed in relation to the criteria defined in the first task. Adequate techniques shall be recommended in order of preference and any required state-of-the-art modifications prescribed. Techniques which are applicable to national disposal sites will be specified.
- Performing Field Surveys and Verification Experiments on Existing Management Procedures. In cases where adequate information to determine the effectiveness of a particular waste management technique are not available, special field surveys or verification experiments will be performed. Results of those studies will be recycled to Task 2 to complete the evaluation of the particular hazardous waste material.
- Defining, Planning and Outlining Research Programs Where Necessary for Elimination of Hazards. Where no acceptable waste management techniques currently exist for a particular hazardous waste material, efforts will be made to innovate new approaches and the necessary research and/or demonstration programs will be planned and outlined. Prioritization of the programs in terms of importance of the problem and probability of success will be accomplished.
- Conducting Proof-of-Principle Experimentation on the Most Promising Concepts. Within the constraints of schedule and budget, proof-of-principle type experimentation will be conducted on the most promising but unproven concepts.

- Determining Waste Forms. Additional information on the hazardous waste materials designated under the earlier tasks as candidates for National Disposal Sites will be collected, analyzed and presented as an integral part of this program. This information will include the forms in which the wastes are found, their location, and the quantities of waste material generated.
- Correlating Total Program Effort. The program is directed to provide inputs to a final report which will: 1) summarize the best available waste management techniques for each material; 2) list on a prioritized basis those techniques to be included at possible National Disposal Sites; and 3) indicate major gaps in current hazardous waste management technology and provide a comprehensive, prioritized research and development plan for obtaining the required technology.

During September effort was concentrated on 1) preparation of the Profile Reports, 2) determination of waste forms, 3) planning of the proof-of-principle experiments, and 4) program coordination. The progress of these efforts is summarized below.

2.1 PROFILE REPORT PREPARATION

During the last month Profile Reports for 28 Category 1 and 53 Categories 2 and 3 chemical compounds (Table 1) were completed and are presented in Appendix A.

The reports complete the Category 1 requirements and account for approximately 30 percent of the Category 2 and 3 materials.

The Profile Report on H^3-tritium completes the radioactive wastes. The other isotopes called out last month (Sodium-14, Titanium-44, etc.) fall into the class of "radioisotopes of commercial interest" covered in the Carbon-14 Profile Report.

TABLE 1. MATERIALS PROFILED

Category I

16 - Aluminum Fluoride
60 - Boric Acid
64 - Bromic Acid
121 - Copper Nitrate
122 - Copper Sulfate
242 - Lead Oxides
243 - Lewisite
245 - Magnesium Arsenite
322 - Pentachlorophenol
324 - Perchloric Acid (to 72 percent strength)
332 - Phosphorus, White or Yellow
349 - Potassium Permanganate
470 - Barium Fluoride
478 - Cadmium Fluoride
514 - Benzoyl Peroxide
515 - 1,2,4-Butanetriol Trinitrate (BTTN)
516 - Chlorates with Red Phosphorus
518 - Copper Chlorotetrazole
524 - Glycerol Monolactate Trinitrate (GLTN)
526 - Gold Fulminate
527 - Hydrazine Azide/Hydrazine
530 - Lead 2,4-Dinitroresorcinate (LDNR)
534 - Nitrocellulose
535 - Polyvinyl Nitrate (PVN)
539 - Silver Styphnate
540 - Silver Tetrazene
541 - Smokeless Gunpowder

Nuclear

Hydrogen-3

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TABLE 1. MATERIALS PROFILED - Continued

Categories 2 and 3

17 - Aluminum Sulfate
18 - Aminoethylethanol Amine
32 - Aniline
56 - Benzene Sulfonic Acid
75 - n-Butylamine
90 - Calcium Chloride
94 - Calcium Hydroxide
95 - Calcium Phosphate
98 - Carbon Disulfide
134 - Cyclohexylamine
150 - Diethanolamine
151 - Diethylamine
155 - Diethylene Trimine
158 - Diisopropanolamine
159 - Dimethylamine
161 - 2,4-Dinitroaniline
173,279 -Ethanolamine (monoethanolamine)
178 - Ethylamine (Monoethylamine)
184 - Ethylene Diamine
210 - Hexamethylene Diamine
231 - Isopropyl Amine
242 - Lead Oxides
247 - Magnesium Oxide
265 - Methylamine
280 - n-Methylaniline
281 - Morpholine
286 - β-Naphthylamine
328 - Phenylhydrazine Hydrochloride
352 - Potassium Sulfate
353 - Potassium Sulfide
359 - Propylamine
364 - Pyridine
413 - Sulfur

Preceding page blank

TABLE 1. MATERIALS PROFILED - Continued

435 - o-Toluidine
441 - Triethanolamine
442 - Triethylamine
444 - Triethylene Tetramine
445 - Trimethylamine
448 - Urea
456 - Zinc Chloride
457 - Zinc Cyanide
459 - Zinc Nitrate
460 - Zinc Oxide
461 - Zinc Permanganate
462 - Zinc Peroxide
463 - Zinc Sulfide
464 - Acridine
465 - Aluminum Oxide
468 - Asbestos
483 - Calcium Oxide
488 - Coal
513 - Vanadium Pentoxide

Preceding page blank

The table summarizing the status of the Category 1 materials is presented in Appendix B.

The remaining Category 2 and 3 Profile Reports will be completed during October. The Profile Report effort will then be directed toward including further information defined in the waste forms analysis and toward increasing process detail where further information has become available since the reports were originally published.

2.2 DETERMINATION OF WASTE FORMS

The effort to determine the forms in which the candidate NDS materials are found was continued through September. The studies on the cadmium compounds and mercury compounds are scheduled for completion during October. During November the study of the chromium compounds, lead compounds, organic pesticides, and inorganic cyanides will be completed and during December the arsenic compounds, copper compounds and organic compounds will be examined. As was mentioned above, these data will be included in the Profile Reports for the corresponding compounds together with a reevaluation of the waste management practices applicable to those wastes and a reassessment of candidacy for National Disposal Site treatment.

2.3 PROOF-OF-PRINCIPLE EXPERIMENTATION

The literature searches, program plans and laboratory efforts associated with the two thus far approved P. O. P. test candidates (arsenic removal from soil and mercury recovery from brines) have continued through September. Samples of soil contaminated with arsenic pesticides have been obtained from agricultural sources and samples of chemical munitions contaminated soil are expected soon. The analytical chemical procedures required for arsenic and mercury determination at the appropriate levels of concentration are currently being tested and evaluated in our laboratories.

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2.4 PROGRAM COORDINATION AND REVIEW

On September 19, a 2-hour review of the program was presented in Cincinnati for NERC personnel and management. The emphasis of the review was to discuss current program status and to alert the research personnel to the thus far indentified needs in the area of Hazardous Waste Disposal. On September 20, a similar review was held in Rockville, Maryland with OSWMP and the other contractors involved in the overall Hazardous Waste Disposal-National Disposal Site Effort. In this second meeting a short status report was given by EPA and by each of the contractors with further discussions directed toward coordinating the various programs and studies.

3. WORK PLANNED FOR OCTOBER

During October the remaining Category 2 and 3 Profile Reports will be written. The upgrading of earlier reports to reflect increased process information and waste form data obtained since their first presentation will be initiated while efforts on the P. O. P. testing will continue.

APPENDIX A - PROFILE REPORTS

PROFILE REPORTS

Aluminum Fluoride (16), Barium Fluoride (470), Cadmium Fluoride (478)

1. GENERAL

Aluminum Fluoride

Aluminum fluoride is a white crystalline solid, used principally as an electrolyte component in the electrolytic reduction and refining of aluminum and as a modifier of glass and enamels in the ceramic industry. Pure anhydrous aluminum fluoride is extremely difficult to prepare; the commercial product contains oxyfluoride. The only simple aluminum fluoride compound occuring in nature is the rare mineral fluellite $AlF_3 \cdot H_2O$. Aluminum fluoride used commercially is manufactured by one of the following processes. In one process used currently aluminum fluoride is prepared batchwise by solution of alumina hydrate in 15 percent hydrofluoric acid, followed by continuous crystallization, filtration, and calcination. In another process, alumina trihydrate is heated to between 400 and 700 C and allowed to react with gaseous hydrogen fluoride or the HF evolved in the electrolytic production of aluminum. The recovered aluminum fluoride is recycled to the molten electrolyte used in the cell. In still another process an ammonium fluoaluminate intermediate is decomposed to aluminum fluoride by heating to 700 C.[1433] The physical/chemical properties for aluminum fluoride are summarized on the attached worksheet.

Barium Fluoride

Barium fluoride forms colorless cubic crystals. It is prepared by treating barium carbonate with hydrofluoric acid. Its principal uses are as a flux and opacifier in enamel frits and as a white pigment in record compositions. It is also used to some extent in metal heat-treating baths and in the manufacture of carbon brushes for electrical generators for aircraft.[1433] The physical/chemical properties for barium fluoride are shown on the attached worksheet.

Cadmium Fluoride

Cadmium fluoride forms white cubic crystals. It is prepared by dissolving cadmium, cadmium carbonate, or cadmium oxide in a solution of hydrogen fluoride and evaporating to dryness. It may also be made by the addition of ammonium fluoride to a solution of cadmium chloride. Cadmium fluoride is used as a fluoride phosphor in cathode-ray-beam tubes and as an impregnating agent in carbon brushes of dynamoes to prevent excessive wear of the brushes.[1433] The physical/chemical properties for cadmium fluoride are summarized in the attached worksheet.

2. TOXICOLOGY

For detailed discussion of fluoride toxicology please refer to the Profile Reports on the alkali and ammonium fluorides (23, etc.). The Threshold Limit Value (TLV) for fluoride dusts is 2.5 milligrams per cubic meter.[0225] The recommended permissible limit criteria for fluoride in drinking water is from 1.7 mg/liter to 0.8 mg/liter, and the recommended maximum concentration for fluoride in water for livestock use is less than 2.4 mg/1.[0536]

The aluminum ion does not contribute to the toxicity of aluminum fluoride. The toxicity of barium fluoride combines the effects of the fluoride and barium ions. The toxicity of barium compounds is discussed in the Profile Report on Barium Compounds (53, etc.). The permissible maximum for barium in public water supplies is 1.0 mg/liter. Cadmium fluoride toxic effects are due to both fluoride and cadmium ions. Cadmium is moderately toxic to all organisms and is a cumulative poison in mammals. The recommended permissible limit in drinking water for cadmium is 0.01 mg/1 and for farmstead use is also 0.01 mg/liter.[0536]

3. OTHER HAZARDS

The fluorides of aluminum, barium and cadmium, when moist or in solution, are corrosive to glass, porcelain, and most common metals of construction except nickel.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Care must be exercised in handling aluminum, barium or cadmium fluorides to prevent contact of the materials with the skin or eyes, and to avoid ingestion or inhalation of dust. Food should not be handled in proximity to these soluble fluorides. There are no current Department of Transportation or Coast Guard regulations which cover shipment or labeling of these fluorides.

Recommended criteria for acceptable disposal of these fluorides are as follows:

Effluent and Environment	Maximum Concentration at Point Source	Basis for Recommendation
Particulate/other fluorides released to the air inside the plant boundaries	2.5 mg/m^3 (as F)	TLV,ACGIH[0225]
Particulate/other fluorides released to the air outside the plant boundaries	0.25 mg/m^3	0.1 TLV
Fluorides released in water to natural water courses or to sewers	Less than the concentration that will raise the receiving water source or sewer to 1.7 mg/l of F	Max. permissible in drinking water[0536]
Barium released in water to natural water courses or to sewers	Less than the concentration that will raise the receiving water course or sewer to 1.0 mg/l of Ba	Max. permissible in drinking water[0536]
Cadmium released in water to natural water courses or to sewers	Less than the concentration that will raise the receiving water course or sewer to 0.01 mg/l	Max. permissible in drinking water[0536]

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

As previously indicated in the Profile Report on Alkali and Ammonium Fluorides (23, etc.) current practice in disposal of many fluorides, except aluminum fluoride in aluminum manufacturing processes, is to vent the material without capture from high temperature operations such as glass manufacture, vitreous enamel processes, and brick manufacture, or to flush the fluoride wastes down the sewer without treatment, where wet collection devices are used for fume abatement.[1688] These practices are unacceptable. In contrast to these current disposal practices, some environmentally acceptable options are discussed in the following paragraphs.

Option 1 - Collection and Return to Process

Aluminum fluoride dusts generated in the handling of the material in the aluminum reduction industry are recovered by mechanical collection devices (cyclones and centrifugal collectors) and returned for reuse to the process system. Aluminum fluoride fumes volatilized from molten electrolyte baths, or mechanically entrained and carried in the vent gases from the electrolytic cells are frequently collected in dry dust abatement devices such as centrifugal collectors, multitube cyclones, and electrostatic precipitators, and recycled to the process for use in the electrolyte. The dusts generated in the preparation of feed for enamel frit furnaces are also frequently recovered by mechanical collectors, and returned for further process use. These abatement and recycle disposal techniques are recommended for use with all mechanically generated aluminum fluoride, barium fluoride and cadmium fluoride dusts. They are also recommended for use, where economically feasible, on thermally generated metal fluoride fumes.

Option 2 - Reaction with Slaked Lime

The Manufacturing Chemists Association recommends packaged lots of soluble or slightly soluble fluorides be slowly added to a large container of water. Then a slight excess of soda ash or slaked lime is stirred into the solution. The slurry formed is allowed to settle for 24 hours.[0955] If aluminum fluoride is being treated, the supernatant liquid is decanted or siphoned into another container, and neutralized with dilute hydrochloric acid before being washed into a sewer or stream with large quantities of water. The sludge is placed in a landfill. If cadmium fluoride is the fluoride being treated, cadmium hydroxide (solubility is 0.0026 g/100g of water) will be precipitated with the slurry formed upon addition of lime. The supernatant liquid will require treatment via another process such as ion exchange, reverse osmosis, or activated carbon absorption to reduce the cadmium content of discharge solutions to less than 0.01 mg per liter of cadmium (See Profile Report on Cadmium and Cadmium Compounds [81, etc.]). If barium fluoride is being treated, the supernatant liquid may be neutralized with sulfuric acid, instead of hydrochloric acid, to form the insoluble barium sulfate. After removal of the barium sulfate by settling, the effluent will contain about 2 ppm of barium. This effluent may be diluted with additional water to meet the permissable criteria of 1.0 ppm for barium in public water supplies (See Profile Report on Barium Compounds [53, etc.]).

Variations on the above technique should be employed where it is necessary to use wet collection techniques to abate metal fluoride fumes generated thermally.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Aluminum, barium and cadmium fluorides are not candidates for National Disposal Sites. Their treatment,either Option 1 or Option 2,is not hazardous, does not require costly or sophisticated apparatus not available to the users, and is economically feasible and technologically practical for waste generation site use. The two disposal options are equally acceptable and selection of the option to be used should be based on economics.

7. REFERENCES

0095. Manufacturing Chemists Association. Laboratory waste disposal manual. 3d ed. Washington, Manufacturing Chemists Association, 1970. 176 p.

0225. American Conference of Government Industrial Hygienists. Threshold limit values for 1971. Occupational Hazards, p. 35-40, Aug. 1971.

0536. Water quality criteria. Report of the National Technical Advisory Committee to the Secretary of the Interior. April 1, 1968. Washington, Federal Water Pollution Administration. 234 p.

1668. Robinson, J. M., G. I. Gruber, W. D. Lusk, and M. J. Santy. v. 1. Engineering and cost effectiveness study of fluoride emissions control. January, 1972. McLean, Virginia, Office of Air Programs, Environmental Protection Agency. 356 p.

1988. Simons, J. H. Editor. v. 1 and v. 4. Fluorine Chemistry. New York, Academic Press, 1940, 1965. 615 p., 786 p.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Barium Fluoride

IUC Name Barium Fluoride

Common Names

Structural Formula

BaF_2

Molecular Wt. 175.36(1) Melting Pt. 1287 C(1) Boiling Pt.

Density (Condensed) 4.89g/cc @ 25 C Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 1.586g/l at 10 C(1) Hot Water 1.620g/l at 30 C(1) Ethanol

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification none Coast Guard Classification none

Comments

References (1) 1433

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Cadmium Fluoride

IUC Name Cadmium Fluoride

Common Names

Structural Formula

CdF_2

Molecular Wt. 150.41[(1)] Melting Pt. 520 C[(1)] Boiling Pt. >1200 C[(1)]

Density (Condensed) 6.64g/cc @ 23 C[(1)] Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water soluble Hot Water Ethanol

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification none Coast Guard Classification none

Comments

References (1) 1433

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Aluminum Fluoride

IUC Name Aluminum Fluoride

Common Names

Structural Formula

AlF_3

Molecular Wt. 83.97(1) Melting Pt. 1040 C(1) Boiling Pt. 1291 C(1)

Density (Condensed) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

16.4 torr @ 1098 C(1) 60.3 torr @ 1144 C(1) 254.7 torr @ 1218 C(1)

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.559 g/100g at 25 C(1) Hot Water Ethanol Insoluble(1)

Others: aqueous hydrofluoric acid - soluble

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification none Coast Guard Classification none

Comments

References (1) 1433

PROFILE REPORT

Aluminum Sulfate (17), Calcium Chloride (90), Calcium Hydroxide (94), Potassium Sulfate (352), Potassium Sulfide (353), Zinc Chloride (456), Calcium Oxide (483)

1. GENERAL

Introduction

The inorganic chemicals in this Profile Report are basically nontoxic. However, they may react violently with water and/or dissolve in water in sufficiently large concentrations to constitute a hazard or nuisance. They are grouped together here in one report because they can be handled by similar disposal processes.

Aluminum Sulfate

Aluminum sulfate, $Al_2(SO_4)_3$, is a white lustrous crystal or powder. The commercial grade is usually produced in the United States directly from bauxite or clay.[1433] Finely ground bauxite is digested with sulfuric acid near the boiling point of the solution. The solids are removed by sedimentation. Unless the bauxite or clay is sufficiently low in iron, the solution may also be treated for iron removal by precipitation of iron compounds, using sulfides of potassium or calcium, hydroxides of calcium or ammonium, etc. In 1960, 1.5 million tons were produced in the United States. Its uses are listed as follows:[1433, 1492]

(1) close to two-thirds of total $Al_2(SO_4)_3$ production is used in the paper industry for clarification of process waters, pH control of pulp slurries, setting of certain dyes and setting of size in paper;

(2) water treatment applications account for another one-fourth of the total production;

(3) the remainder $Al_2(SO_4)_3$ goes into manufacture of chemicals, pharmaceutical preparations, dyeing operations, soaps and grease, fire-extinguishing solutions, tanning leather, waterproofing concrete, fireproofing and waterproofing cloth, deodorizing and decolorizing petroleum.

Calcium Chloride

Calcium chloride, $CaCl_2$, is a colorless cubic crystal, very hygroscopic. When dissolved in water, much heat is liberated. Commercially, about 50 to 60 percent of the calcium chloride sold in the United States is manufactured from natural brines.[1433] In 1961, total U.S. production of $CaCl_2$ was 558,352 tons flake (77-80 percent) and 226,636 tons liquor (40-45 percent). Its uses are:[1433, 1492]

(1) as a drying and dehydrating agent for organic liquids and in desiccators;

(2) drying gases in chemical analysis;

(3) in brine making in refrigeration plants;

(4) in control of snow and ice on highways, streets;

(5) in dust control on secondary roads, unpaved streets and highway shoulders;

(6) in freezproofing of coal and ores, both in shipping and stockpiling;

(7) in concrete mixes to give quicker initial set, high early strength and greater ultimate strength.

Calcium Hydroxide

Calcium hydroxide, $Ca(OH)_2$, also known as slaked lime, is a colorless, orthorhombic or trigonal crystal, or soft, odorless powder and granules. It readily absorbs CO_2 from air. When ignited, it loses water to form CaO. Commercially, it is prepared from brine, CaO.[1433].

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

Its uses are:[1492]

(1) manufacture of mortars, plasters, and cements;

(2) manufacutre of soda ash by the Solvay process;

(3) in dehairing hides;

(4) in water paints;

(5) as antiemetic and in infant feeding formulas to decrease sizes of curds formed from cows' milk.

Potassium Sulfate[1433]

Potassium sulfate, K_2SO_4, is a colorless crystal of rhombic or hexagonal form. It occurs in nature as the mineral arcanite. Commercially, it is obtained from the langbeinite ore, $K_2SO_4 \cdot 2MgSO_4$. It is also one of the many products recovered from the Searles Lake brine. In an unusual situation where HCl is valuable, it can be prepared as shown in the following reaction:

$$2KCl + H_2SO_4 \longrightarrow K_2SO_4 + 2HCl$$

Finally, it can also be produced by burning sulfur with excess of air mixed with steam and then passing the gaseous mixture through a bed of porous KCl briquets.

$$4KCl + 2SO_2 + O_2 + 2H_2O \longrightarrow 2K_2SO_4 + 4HCl$$

The U.S. production of potassium sulfate is about 500,000 tons/year. Its uses are:

(1) as fertilizers (technical grade product);

(2) in the manufacture of potassium alum ($KAl(SO_4)_4 \cdot 12H_2O$), potassium carbonate, and glass;

(3) in the manufacture of SBR latex rubber;

(4) in smokeless powder;

(5) as analytical reagent.

Potassium Sulfide[1492]

Potassium sulfide, K_2S, is a yellow to brown crystal of cubic form. It is very hygroscopic and unstable. It discolors in air. It may be prepared from reaction of potassium with sulfur in liquid ammonia. Commercially, it is manufacutred by (1) heating potassium sulfate with coal:

$$K_2SO_4 + 4C \longrightarrow K_2S + 4CO$$

or (2) reacting potassium hydroxide with hydrogen sulfide:

$$KOH + H_2S \longrightarrow KSH + H_2O$$

$$KOH + KSH \longrightarrow K_2S + H_2O$$

Potassium sulfide has little use except as a laboratory reagent and as a depilatory.

Zinc Chloride

Zinc chloride, $ZnCl_2$, is a white hexagonal crystal. It is very deliquescent and highly soluble in water. Industrially, it is produced by heating the roasted zinc sulfide ore with common salt.[1433] The fume contains mostly zinc chloride and some lead chloride, and is then treated with sulfuric acid or zinc sulfate to precipitate the lead as lead sulfate. The clear liquid is evaporated to a concentrated solution of zinc chloride from which crystals of zinc chloride are obtained on cooling. It can also be prepared from reacting crude zinc oxide or zinc dross with HCl. Zinc chloride is one of the more industrially important zinc compounds. Its uses are:[1433, 1492]

(1) as a deodorant, disinfecting and embalming material;

(2) in preserving railway ties and fireproofing lumber;

(3) as a flux in soldering;

(4) in etching metals, browning steel, galvanizing and copperplating iron;

(5) in making parchment paper, artifical silk, dyes, activated carbon, cold-water glues, and vulcanized fiber;

(6) as a mordant in dyeing and printing textiles;

(7) in mercerizing cotton, sizing and weighing fabrics, carbonizing woolen goods;

(8) in vulcanizing rubber;

(9) as a dehydrating agent in chemical synthesis;

(10) topically as an antiseptic and astringent.

Calcium Oxide

Calcium oxide, CaO, also known as lime or quicklime, is white or grayish-white lumps or granular powder. On exposure to air it absorbs CO_2 and water becomes air-slaked. With a little water it generates much heat and is converted to $Ca(OH)_2$, the slaked lime. Industrially, it is manufactured from calcination of limestone ($CaCO_3$) in a kiln.[1433]

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$$

In 1964, 13.5 million tons of CaO were produced in the United States, Its uses are:[1433, 1492]

(1) in the manufacture of mortar and plaster;

(2) in various metallurgical processes, for example, as a flux and in forming a molten slag which purifies the metal in the production of pig iron and steel;

(3) in the manufacture of slaked lime, $Ca(OH)_2$;

(4) as a desiccant;

(5) in the manufacture of bleaching agents, pesticides, inorganic and organic salts of calcium, and chlorinated lime;

(6) in water purification and treatment for potable and industrial purposes;

(7) in paper pulp processing;

(8) in the manufacture of glass and ceramics;

(9) in deodorizing vegetable oils and dehairing hides.

Sources and Types of Wastes

The main sources of wastes for the materials in this report are:

(1) manufacturers of these materials;

(2) the paper and water treatment industries;

(3) various metallurgical operations and processes;

(4) highway and streets maintainence operations;

(5) construction industry;

(6) farming operation;

(7) chemical laboratories and plants using these materials as chemical reagents;

(8) textile, rubber, glass and ceramics industries.

The wastes may include contaminated materials and process wastes in the form of solid or aqueous solution.

Physical and Chemical Properties

The physical and chemical properties of the inorganic chemicals treated in this report are given in the attached worksheets.

2. TOXICITY[0225, 0766, 1312, 1492]

The materials treated in this report should not be considered toxic unless they contain a toxic compound such as arsenic. However, they are all soluble in or reactive with water to yield solutions or products which may be corrosive or toxic.

When dry, aluminum sulfate is harmless. When dissolved in water, it hydrolyzes readily to form sulfuric acid which is corrosive and would cause rapid destruction of body tissue on contact.

Generally speaking, calcium compounds are nontoxic. In fact, many calcium compounds are used medicinally. Calcium chloride is completely innocuous. Calcium hydroxide and oxide are the only calcium compounds which may be considered toxic. They have caustic reaction and therefore are irritating to the skin and respiratory system. In the form of dust, calcium hydroxide can cause dermatitis and irritation of the eyes and mucous membranes.

Potassium sulfate is nontoxic. Potassium sulfide is similar to alkali in action. It causes softening and irritation of the skin. If taken by mouth, it is corrosive and irritant through the liberation of hydrogen sulfide and free alkali. Hydrogen sulfide is toxic.

Because of its caustic action, zinc chloride can cause ulceration of the fingers, hands and forearms of those who use it as a flux in soldering. Soluble salts of zinc, including zinc chloride, have a harsh metallic taste; small doses can cause vomiting and nausea, while larger doses cause violent vomiting and purging. However, continued administration of zinc salts in small doses has no effect in man except those of disordered digestion and constipation. Exposure to zinc chloride fumes can cause damage to the mucous membranes of the nasopharnyx and respiratory tract and give use to a pale gray cyanosis. Inhalation of high concentrations of zinc chloride fume can cause lung damage resulting in fatalities.

The Threshold Limit Value (TLV) recommended by the American Conference of Governmental Industrial Hygienists and the lethal doses reported are given in the following table:

Contaminant	TLV, mg/M^3	Lethal Dose
Aluminum Sulfate	--	or LD_{50} 770 mg/kg mouse
Calcium Chloride	--	or LD_{50} 4000 mg/kg rat
Calcium Hydroxide	--	or LD_{50} 7340 mg/kg rat
Potassium Sulfate	--	sc LD_{Ca} 3000 mg/kg guinea pig
Potassium Sulfide	--	--
Zinc Chloride	1 (fume)	iv LD_{Ca} 75 mg/kg rat
Calcium Oxide	5	--

3. OTHER HAZARDS

Potassium sulfide may explode on percussion or rapid heating. When exposed to flame or by spontaneous chemical reaction, it may cause moderate fire hazard.

Calcium chloride and calcium oxide generate much heat when dissolved in water due to the heat of solution and the reaction to calcium hydroxide in the latter case.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, and Transportation

In storage, the materials in this report should be kept tightly closed and dry, because most of them would absorb moisture and/or carbon dioxide from the air. Adequate ventilation and dust control should be maintained particularly for storing and handling zinc chloride and calcium hydroxide. In shipping, potassium sulfide is classified by Coast Guard and DOT as inflammable solid.

Disposal/Reuse

Industrially, contaminated materials probably will not be considered for reprocessing for reuse based on economic considerations. Safe disposal of these waste materials is here defined in terms of the recommended maximum exposure limit in air and in potable water source.

Contaminant in Air	Maximum Exposure Limit	Basis for Recommendation
Zinc Chloride (fume)	0.01 mg/M^3/24 hr	0.01 TLV
Calcium Oxide (dust)	0.05 [illegible]g/M^3/24 hr	0.01 TLV

Contaminant in Water	Maximum Allowable Concentration	Basis for Recommendation
Aluminum Sulfate	250 mg/l	U.S. Public Health Service[1752] Drinking Water Standards
Potassium Sulfate	250 mg/l	U.S. Public Health Service[1752] Drinking Water Standards
Calcium Chloride	250 mg/l	U.S. Public Health Service[1752] Drinking Water Standards
Zinc Chloride	5 mg/l	U.S. Public Health Service[1752] Drinking Water Standards

There is no specific recommendation by the U.S. Public Health Service regarding the drinking water standards for potassium sulfide, calcium hydroxide and calcium oxide. However, they do recommend a maximum allowable concentration of 500 mg/l for dissolved solids. This recommendation seems to be applicable for potassium sulfide, calcium hydroxide and oxide.

5. EVALUATION OF WASTE DISPOSAL PROCESSES

Since the materials in this report do not all belong to the same chemical family, slightly different processes are required for their disposal.

Option No. 1 - Hydrolysis and Neutralization for Aluminum Sulfate

Aluminum sulfate can be readily hydrolyzed to yield aluminum hydroxide and sulfuric acid.

$$Al_2(SO_4)_3 + 6H_2O \longrightarrow 2Al(OH)_3 + 3H_2SO_4$$

The sulfuric acid formed is neutralized by NaOH and the insoluble aluminum hydroxide is removed by filtration. The latter may be heated to decomposition to yield alumina which has valuable industrial applications.

$$2Al(OH)_3 \xrightarrow{\Delta} Al_2O_3 + 3H_2O$$

The neutral solution of sodium sulfate may then be safely discharged into sewers or waterways as long as its concentration is below the recommended maximum level of 250 mg/liter.

Option No. 2 - Carbonate Precipitation for the Chlorides

Calcium and zinc chloride can be treated with soda ash to yield the insoluble calcium and zinc carbonate respectively.

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaCl$$

$$ZnCl_2 + Na_2CO_3 \longrightarrow ZnCO_3 + 2NaCl$$

After removing the carbonate precipitate by filtration, the remaining brine solution, when its sodium chloride concentration is below 250 mg/liter may be discharged into sewers or any other waterways. Calcium carbonate may be calcined to yield the quicklime, CaO.

$$CaCO_3 \xrightarrow[800\ C]{\Delta} CaO + CO_2$$

Similarly, zinc carbonate can be heated to decomposition to yield zinc white, ZnO.

$$ZnCO_3 \xrightarrow[300\ C]{\Delta} ZnO + CO_2$$

Lime and zinc white both have many industrial uses and therefore are valuable by-products.

Option No. 3 - Neutralization and Carbonate Precipitation for CaO and $Ca(OH)_2$

Contaminated calcium oxide and hydroxide can be neutralized by hydrochloric acid to yield calcium chloride.

$$Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O$$

The calcium chloride formed can now be treated as described in Option No. 2. Since calcium chloride is nontoxic, the neutral aqueous calcium chloride solution could also be diluted to a concentration below 250 mg/liter and discharged directly to sewers, rivers, lakes, oceans, or any other waterways.

Option No. 4 - Sulfide Precipitation for K_2S

Potassium sulfide can be converted into insoluble FeS by ferric chloride solution. After removing the FeS precipitate by filtration, the remaining potassium chloride solution can be diluted to a concentration level below 250 mg/liter and discharged to sewers, rivers, lakes, oceans, or any other waterways. If excess ferric chloride solution has been used to precipitate out FeS, the remaining solution should be neutralized with soda ash followed by filtration and discharge of the waste liquid.

Option No. 5 - Dilution and Discharge

Potassium sulfate and calcium chloride are relatively harmless. Dilute solutions of these two chemicals can be released into streams and bays under careful monitoring and control to ensure that their concentration levels are below the recommended maximum of 250 mg/liter.

In summary, the materials in this report are generally innocuous and soluble in water. The contaminated waste can be dissolved in water to form a dilute solution and discharged into streams or bays under careful control. If the waste solution is acidic (as that of aluminum sulfate) or caustic (as that of calcium hydroxide), they should be neutralized with soda ash or hydrochloric acid, filtered to remove the solid, diluted and then discharged.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

As mentioned at the beginning of this report, the chemical compounds discussed here have been preliminarily classified as probable candidates for municipal disposal. Based on the discussion of disposal processes, it may be concluded that the waste treatment for these compounds can be adequately handled locally and no consideration for National Disposal Site is warranted.

7. REFERENCES

0225. American Conference of Governmental Industrial Hygienists. Threshold limit values for 1971. Occupational Hazards, Aug. 1971. p. 35-40.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 1,251 p.

1312. Christensen, H. E., ed. Toxic substances annual list 1971. Washington, U.S. Government Printing Office, 1971. 512 p.

1433. Kirk-Othmer encyclopedia of chemical technology. 2d ed. New York, Interscience Publishers, 1966.

1492. The Merck index of chemicals and drugs. 7th ed. Rahway, New Jersey, Merck Company, Inc., 1960. 1,634 p.

1570. Weast, R. C., ed. Handbook of chemistry and physics. 48th ed. Cleveland, Ohio, Chemical Rubber Company, 1969. 2,100 p.

1752. Public Health Service. Drinking water standards, 1962. Washington, U.S. Department of Health, Education, and Welfare, 1969.

17

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Aluminum Sulfate

IUC Name ______

Common Names ______

Structural Formula

$Al_2(SO_4)_2$

Molecular Wt. 342.15(1)

Melting Pt. decomposes @ 770 C(1)

Boiling Pt. ______

Density (Condensed) 2.71(1) @ ______ ______

Density (gas) ______ @ ______ ______

Vapor Pressure (recommended 55 C and 20 C)

______ @ ______ ______ @ ______ ______ @ ______

Flash Point ______

Autoignition Temp. ______

Flammability Limits in Air (wt %) Lower ______ Upper ______

Explosive Limits in Air (wt. %) Lower ______ Upper ______

Solubility(1)

Cold Water 31.3 grams/100 ml @ 0 C

Hot Water 98.1 grams/100 ml @ 100 C

Ethanol slightly soluble

Others: soluble in dilute acids

Acid, Base Properties ______

Highly Reactive with ______

Compatible with ______

Shipped in ______

ICC Classification ______

Coast Guard Classification ______

Comments ______

References (1) 1570

HAZARDOUS WASTES PROPERTIES WORKSHEET

90

H. M. Name Calcium Chloride

IUC Name

Common Names

Structural Formula

$CaCl_2$

Molecular Wt. 110.99(1) Melting Pt. 772 C(1) Boiling Pt. > 1160 C(1)

Density (Condensed) 2.15 @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility(1)

Cold Water 74.5 grams/100 ml @ 20 C Hot Water 159 grams/100 ml @ 100 C Ethanol soluble

Others: soluble in acetic acid, acetone

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Calcium Hydroxide

IUC Name

Common Names

Structural Formula

$Ca(OH)_2$

Molecular Wt. 74.09(1) Melting Pt. - H_2O @ 580 C(1) Boiling Pt. decomposes(1)

Density (Condensed) 2.24 @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility(1)

Cold Water 0.185 grams/100 ml @ 0 C Hot Water 0.077 grams/100 ml @ 100 C Ethanol insoluble

Others: soluble in acids and ammonium salts

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

352

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Potassium Sulfate

IUC Name

Common Names

Structural Formula

K_2SO_4

Molecular Wt. 174.27(1) Melting Pt. 1069 C(1) Boiling Pt. 1689 C(1)

Density (Condensed) 2.662 @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility(1)

Cold Water 12 grams/100 ml @ 25 C Hot Water 24.1 grams/100 ml @ 100 C Ethanol insoluble

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

353

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Potassium Sulfide

IUC Name

Common Names

Structural Formula

K_2S

Molecular Wt. 110.27(1)   Melting Pt. 840 C(1)   Boiling Pt.

Density (Condensed) 1.805 @   Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@   @   @

Flash Point   Autoignition Temp.

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility(1)

Cold Water soluble   Hot Water very soluble   Ethanol soluble

Others: soluble in glycerin

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification flammable solid(2) yellow label   Coast Guard Classification inflammable(2) solid, yellow label

Comments

References (1) 1570
(2) 0766

456

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Zinc Chloride

IUC Name

Common Names

Structural Formula

$ZnCl_2$

Molecular Wt. 136.28(1)   Melting Pt. 283 C(1)   Boiling Pt. 732 C(1)

Density (Condensed) 2.91 @   Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@   @   @

Flash Point   Autoignition Temp.

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility (1)

Cold Water 432 grams/100 ml @ 25 C Hot Water 615 grams/100 ml @ 100 C Ethanol 100 grams/100 ml @ 12.5 C

Others: very soluble in ether

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification   Coast Guard Classification

Comments

References (1) 1570

HAZARDOUS WASTES PROPERTIES
WORKSHEET

483

H. M. Name Calcium Oxide

IUC Name ____________

Common Names ____________

Structural Formula

CaO

Molecular Wt. 56.08(1) Melting Pt. 2580 C(1) Boiling Pt. 2850 C(1)

Density (Condensed) 3.25 - 3.38 @ ____ ____ Density (gas) ________ @ ______ ______

Vapor Pressure (recommended 55 C and 20 C)

________ @ ________ ________ @ ________ ________ @ ________

Flash Point ________ Autoignition Temp. ____

Flammability Limits in Air (wt %) Lower ________ Upper ________

Explosive Limits in Air (wt. %) Lower ________ Upper ________

Solubility (1)

Cold Water decomposes 0.131 grams/100 mg @ 10 C Hot Water decomposes 0.07 grams/100 mg @ 80 C Ethanol ________

Others: soluble in acids

Acid, Base Properties ________

Highly Reactive with ________

Compatible with ________

Shipped in ________

ICC Classification ________ Coast Guard Classification ________

Comments ________

References (1)

PROFILE REPORT
ALIPHATIC AMINES:

Aminoethylethanol Amine (18), n-Butylamine (75), Cyclohexylamine (134), Diethanolamine (150), Diethylamine (151), Diethylene Trimine (155), Diisopropanolamine (158), Dimethylamine (159), Ethanolamine (Monoethanolamine) (173,279), Ethylamine (Monoethylamine)(178), Ethylene Diamine (184), Hexamethylene Diamine (210), Isopropyl Amine (231), Methylamine (265), Morpholine (281), Propylamine (359), Triethanolamine (441), Triethylamine (442), Triethylene Tetramine (444), Trimethylamine (445), Urea (448).

1. GENERAL

Introduction

The aliphatic amines treated in this report have all been selected as probable candidates for industrial disposal. These materials are similar in that most are commodity chemicals with relatively low toxicity, good biodegradability, well-defined, safe methods of industrial handling and common methods of disposal. The aliphatic amines are, therefore, discussed as a class in this report.

Manufacture

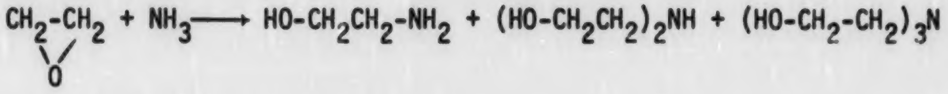
The compounds in this group are made by a wide variety of methods, some of which are specific to a given compound. The common industrial procedures representing over 95 percent of the total production of this group will be discussed here.[1718]

Most processes for manufacturing aliphatic amines involve the displacement of a reactive functional group from the appropriate aliphatic compound. The resulting mono substituted amine then competes with ammonia for unreacted starting material to produce a disubstituted amine which can then react further to produce a trisubstituted amine. Varying the proportions of the starting materials and reaction conditions can result in a preponderance of the mono-, di-, or tri-substituted product, but the selectivity to the desired amine is rarely greater than 70 to 80 percent, requiring each plant to have extensive purification facilities to separate the isomers.[1655,1501,1433,1434]

The reaction of ammonia with an alcohol or alkyl chloride produces alkyl amines. The alcohol-ammonia reaction (Equation 1) is a gas phase process that requires a dehydration catalyst, or a hydrogenation catalyst in the presence of hydrogen. The alkyl chloride-ammonia reaction (Equation 2) is a batch process that is carried out under pressure in an autoclave. The alcohol-ammonia reaction is favored in most cases since the alcohol is cheaper than the alkyl chloride and there is no problem with the disposal of ammonium chloride or hydrochloric acid.[1501,1433,1434]

$$CH_3OH + NH_3 \longrightarrow CH_3NH_2 + (CH_3)_2NH + (CH_3)_3N + H_2O \qquad (1)$$

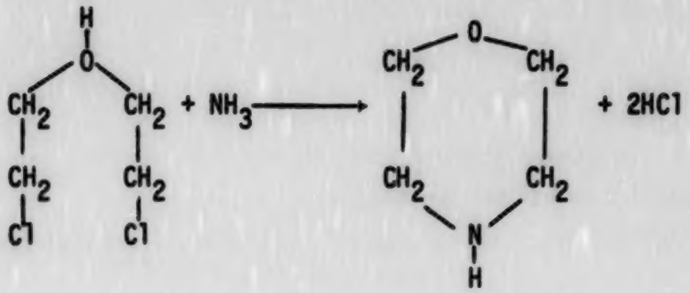
$$CH_3Cl + NH_3 \longrightarrow CH_3NH_2 + (CH_3)_2NH + (CH_3)_3N + NH_4Cl \qquad (2)$$

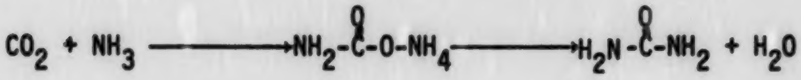


$$\underset{\diagdown\!\diagup \atop O}{CH_2\text{-}CH_2} + NH_3 \longrightarrow HO\text{-}CH_2CH_2\text{-}NH_2 + (HO\text{-}CH_2CH_2)_2NH + (HO\text{-}CH_2\text{-}CH_2)_3N \qquad (3)$$

$$Cl\text{-}CH_2CH_2\text{-}Cl + NH_3 \longrightarrow H_2N\text{-}CH_2CH_2\text{-}NH_2 + H_2N\text{-}CH_2\text{-}CH_2\text{-}NH\text{-}CH_2CH_2\text{-}NH_2$$

$$+ H_2N\text{-}CH_2\text{-}CH_2\text{-}NH\text{-}CH_2\text{-}CH_2\text{-}NH_2\text{-}CH_2\text{-}CH_2\text{-}NH_2 \qquad (4)$$


(5)



$$CO_2 + NH_3 \longrightarrow NH_2-\overset{O}{\overset{\|}{C}}-O-NH_4 \longrightarrow H_2N-\overset{O}{\overset{\|}{C}}-NH_2 + H_2O \qquad (6)$$

$$CH_2{=}CH-CH{=}CH_2 \xrightarrow{Cl_2} ClCH_2-CH{=}CH-CH_2Cl \xrightarrow{NaCN}$$

$$NC-CH_2-CH{=}CH-CH_2-CH \xrightarrow{H_2} H_2N-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-NH_2 \qquad (7)$$

The reaction of aqueous ammonia and ethylene or propylene oxide at 50-60 C is used to manufacture the mono-, di-, and tri-ethanol or propanol amines, respectively (Equation 3). If ethylene dichloride and aqueous ammonia are reacted in an autoclave under pressure at 100 to 180 C, a mixture of ethylene diamide, diethylene triamine tetraamine and higher poly amines are produced (Equation 4). Morpholine is produced by reacting sym-dichloroethyl ether with ammonia under pressure at 50 C (Equation 5). Urea is produced by the reaction of carbon dioxide with ammonia at 150-200 C and 150 to 300 atm pressure. Hexamethylene diamine is made by several processes, often in conjunction with sebacic acid. One of the most important routes is given below (Equation 7).[1501,1433,1434]

Uses

The two amines that account for more than 80 percent of the total production in this group are urea and hexamethylenediamine. Urea is used as a fertilizer, cattle feed and in resins, while hexamethylenediamine is used in the production of nylon 6,6 and 6,10.[1506,1718,1433]

The remaining amines have a wide variety of uses as chemical intermediates and in formulations of various types. These include detergent manufacture (ethanol and isopropanol amines, isopropylamine, ethylenediamine, diethylene triamine and triethylene tetraamine); soaps, waxes and emulsifiers (alkylamines, ethylene diamines, etc.); corrosion inhibitors (alkylamines, cyclohexylamine); complexing and chelating agents (di-, tri-, and polyamines); in resins, and as reactive resin curing agents and polymerization catalysts; antioxidants; rubber chemicals; and insecticides and fungicides (methyl amine, ethylenediamine). The ethanol amines are used for gas scrubbing: dimethylamine is used in the production of dimethyl formamide and dimethyl acetamide; and morpholine is used in the production of optical brighteners for detergents. A detailed list of uses can be found in standard reference sources,[1433,1434,1506] and manufacturers data sheets.[2298,2299]

Physical and Chemical Properties

The physical and chemical properties of the compounds discussed in this report are included in the attached worksheets.

2. TOXICOLOGY[0766,1433,2298,2299,2343]

The amines in this report are all relatively strong bases and thus share to some extent, the corrosive and damaging effect on tissue that are characteristic of the alkaline and alkaline earth hydroxides. Thus all liquid amines severely damage the eyes, ingestion causes severe internal corrosive injury, and prolonged contact with the skin can cause serious skin burns. In addition, amine vapors are painful and irritating to the eyes, nose, throat and respiratory system. However, most people find these vapors so repulsive that they will leave the area before serious injury occurs.

Repeated exposure to amines, especially diamines, and to a lesser extent, the ethanol amines, has been known to produce hypersensitivity, dermatitis and to precipitate allergenic and asthmatic reactions in some people.

The amines in this report are not particularly toxic systematically and while their toxicological properties have not been extensively investigated, it is felt that ingestion or absorption of quantities of amines that do not cause local injury, presents little danger to non-sensitive individuals. Chronic ingestion of amines that can be tolerated locally in larger quantities due to low basicity and chronic ingestion of those compounds with more than one amino group per molecule have been shown in some cases to cause liver and kidney damage.

Ingestion of cyclohexyl amines is reputed to cause convulsions in some cases. Urea has no importance as an industrial hazard.

The known Threshold Limit Values are listed below:

	TLV	
Compound	ppm	mg/M^3
Butylamine	5	15
Cyclohexylamine	25	100
Diethylamine	25	75
Dimethylamine	10	18
Ethylamine	10	18
Isopropylamine	5	12
Methylamine	10	12
Propylamine	N/A	N/A
Triethylamine	25	100
Trimethylamine	N/A	N/A
Ethylenediamine	10	25
Hexamethylenediamine	N/A	N/A
Dethylenetriamine	1	4
Triethylenetetramine	N/A	N/A
Monoethanolamine	3	6
Diethanolamine	N/A	N/A
Diisopropanolamine	N/A	N/A
Triethanolamine	N/A	N/A
Aminoethanol amine	N/A	N/A
Morpholine	20	70
Urea	N/A	N/A

3. OTHER HAZARDS

The aliphatic amines burn cleanly without residue.[2297] However, when heated to decomposition, they may emit noxious, irritating and toxic fumes.[0766] In addition, these compounds will react vigorously to form potentially explosive mixtures with calcium and sodium hypochlorite and with alkaline and alkaline earth metals.[1569] Direct contact of alkylamine vapors with mercury can cause an explosion. Amines can cause the explosive decomposition of maleic anhydride.[1569] These compounds have a wide range of flammability and tendency to explode (noted in the respective worksheets); none are shock-sensitive or subject to detonation.[0766].

4. DEFINITION OF WASTE MANAGEMENT PRACTICES

Handling, Storage and Transportation

The aliphatic amines are all toxic to a certain extent by inhalation or skin contact. In addition, they are very corrosive to eyes and can cause minor to severe primary skin irritation on contact. Thus, these materials should be handled in a well-ventilated area and protective clothing and respirators are recommended where necessary. In cases of accidental contact, all contaminated clothing should be removed instantly and the skin washed thoroughly with soap and water.[0766].

Storage of these materials should be in cool, dry, well-ventilated areas, away from acute fire hazards. Materials with low boiling points should be protected from excessive heat and against sudden rise in temperature. Liquid materials that can solidify should be liquified completely before transfer in order to obtain uniform material.[2298,2299]

These materials are shipped under a variety of U.S. Department of Transportation, Coast Guard and IATA regulations. Most regulations relate to the flammability and volatility of the compounds. Information on safe handling and use of these compounds can be found in the Chemical Data Sheets published by the Manufacturing Chemists Association[2340,2341,2342] Standard Reference Sources[0766,1433,1434] or manufacturers' technical data sheets.[2298,2299,2340,2341,2342]

Disposal/Use

Commercial operators use aliphatic amines in literally hundreds of applications. In many cases, the amine is used as an additive to improve the performance of a given formulation. Disposal of amines used in this manner is best considered in respect to the major component of the formulation. Since many of these formulations are sold as consumer items, detrimental environmental effects can not be controlled except by reformulation. Aliphatic amines are also used as chemical intermediates in the production of detergents, emulsifiers, soaps, waxes, nylon, resins, catalysts, insecticides, fungicides, optical brighteners and other chemicals. In these cases, the chemical form of the amines is changed and disposal is best considered in respect to the new compound.[1506,1433,1434,2298,2299]

In manufacture, enormous amounts of research has gone into determining the reaction conditions that allow production of a reaction mixture of mono-, di-, and tri-amines that corresponds to sales demand. Unfortunately, this is not always the case and a given manufacturer must store the unused amine until a use can be found for it. This represents a serious potential disposal problem.[1433,1501,1718]

The manufacture of urea has been developed to the point where there is close to 100 percent utilization of all raw materials and reaction products as various grades of animal feed and fertilizer.[0314]

All the compounds treated in this report, with the exception of urea, require extensive purification to separate the various products. Usable or potentially usable products generally account for more than 90 to 95 percent of the total raw material. This material or "heavy bottoms" is presently disposed of by incineration, landfill, deep well injection or processed to reduce biological and chemical oxygen demand.[1433,1501]

Most, if not all, manufacturing procedures for the production and use of amines produce dilute waste streams of nitrogen containing materials. These materials are presently disposed of by discharge into municipal sewer systems or rivers, with or without pre-treatment to reduce chemical and biological oxygen demand or deep well injection. Since amines have strong obnoxious odors, the pH of the effluent must be controlled to prevent escape of the amine into the atmosphere.

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Recommended air and water standards are listed below. The air standard is 0.01 TLV and the water standard is 0.01 TLV by weight in 2 liters of water.

Substance	Limit for Air (Man) ppm	Limit for Air (Man) mg/M^3	Limit for Water (Man) ppm or mg/l	Limit for Water (Fish) ppm or mg/l
Methylamine	0.10	0.12	0.60	3.0
Ethylamine	0.10	0.18	0.90	3.0
Propylamine				2.0
Isopropylamine	0.05	0.12	0.60	4.0 - 8.0
Butylamine	0.05	0.15	0.75	4.0
Dimethylamine	0.10	0.18	0.90	3.0
Diethylamine	0.25	0.75	3.75	10.0
Trimethylamine				25
Triethylamine	0.25	1.0	5.0	8
Cyclohexylamine				
Ethyleneamine	0.005	0.01	0.05	1 - 10
Ethylenediamine	0.10	0.25	1.27	3.0
Hexamethylenediamine				
Diethylenetriamine	0.01	0.04	0.20	1 - 10
Triethylene tetramine				
Monoethanolamine	0.03	0.06	0.30	7.5
Diethanolamine				10.0
Diisopropanolamine				0.40
Triethanolamine				0.20
Aminoethanol amine				
Morpholine				
Urea				

5. EVALUATION OF WASTE MANAGEMENT PRACTICES

Option No.1 - Reformulation of Products to Reduce Environmental Impact

A large portion of the amine compounds treated in this report are consumer products or are used industrially in such a manner that they are discharged directly into the environment either during or directly after use.[1433,1434,2298,2299] Since conventional waste management practices are very difficult or impossible to apply under these conditions, reformulation with or use of alternative materials that have less environmental impact is recommended when necessary.

Option No.2 - Treatment of Waste Water and Water Soluble By-products to Reduce Biological and Chemical Oxygen Demand

Aliphatic amine compounds, as well as by-products of use and production, can be chemically and biologically degraded very easily, making this method the ideal way for waste disposal.[1543] Depending on the quality and quantity of effluent that must be treated, treatment can be carried out at the manufacturing site and/or by the municipal waste treatment system. Final discharge should meet water quality standards.

Option No.3 - Incineration

Badly contaminated amines that cannot be reclaimed, as well as by-products that cannot be sold and unusable end-products, can be disposed of by incineration. A scrubber may be necessary to reduce NO_x to required levels.

Option No.4 - Landfill or Residue and Sludges Obtained During Manufacturing or Use

Deposit by landfill of amine-containing waste presents a serious long-term environmental hazard to man, animals and fish. These materials are toxic and to some extent water soluble. Biodegradation of polymers or polyamines will further increase mobility by molecular weight reduction. Thus, landfill disposal of these wastes represents an excessive, long-term threat to underground water supplies and must be considered much less acceptable than Option No.2 (incineration). Option No.3 is acceptable only when landfill sites are totally isolated from ground and surface water.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Most of the wastes generated by the industries that produce and use these materials can be handled and treated locally by incineration and conventional water treatment. Wastes presently landfilled should be incinerated. Incineration should be available at the National Disposal Site where the industry that is generating the waste has a special problem or cannot handle certain wastes safely.

7. REFERENCES

0314 Jones, H.E., Environmental control in the organic and petrochemical industries. Park Ridge, New Jersey, Noyes Data Corporation, 1971.

0766 Sax, I.R., Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 1,251 p.

1433 Kirk-Othmer encyclopedia of chemical technology. 3d ed. 22 V. New York, Interscience Publishers, 1966.

1434 Kirk-Othmer encyclopedia of polymer science and technology. 12 V. New York, Interscience Publishers, 1964-1970.

1501 Faith, W.L., D.B. Keyes, and R.L. Clark. Industrial chemicals. 3d ed. New York, John Wiley and Sons, Inc.,1965. 824 p.

1506 Oil, paint and drug reporter profiles. New York, Schnell Publishing Company, Inc., 1970.

1543 Ludzack, F.J., M.B. Ettinger. Chemical structures resistant to aerobic chemical stabilization. Journal Water Pollution Control Federation, 32(11):1173-1200, Nov. 1960.

1569 Manual of hazardous chemical reactions. Boston National Fire Protection Association, 1971. 308 p.

1655 Fieserm L.F. and M. Fieser, Organic chemistry. 3d ed. Boston, P.C. Heath & Company, 1956. p 145-160, 644-655.

1718 Synthetic organic chemicals, U.S. production and sales. U.S. Government Printing Office, Washington, D.C., Publication TC-479, 260 p.

2298 Technical data sheet for alkyl and alkylene amines. New York, Union Carbide Chemicals Company, 1960. 48 p.

2299 Technical data sheet for alkanolamines and morpholines. New York, Union Carbide Chemicals Company, 1960. 53 p.

2340 Methyl amines chemical safety data sheet., SD-57. Washington., Manufacturing Chemists Association, 1955. 20 p.

2341 Isopropylamine chemical safety data sheet, SD-72. Washington., Manufacturing Chemists Association, 1959. 13 p.

2342 Diethylene triamine chemical safety data sheet, SD-76. Washington., Manufacturing Chemists Association, 1959. 15 p.

2343 Gleason, M.M., R.E. Gusselin and H.C. Hodge, Chemical toxicology of commercial products., Baltimore, The Williams and Wilkins Company, 1960. 53 p.

HAZARDOUS WASTES PROPERTIES WORKSHEET

184

H. M. Name Ethylene diamine

IUC Name 1,2-diaminoethane

Common Names ethylene diamine, 1-2 ethanediamine

Structural Formula

$NH_2CH_2CH_2NH_2$

Molecular Wt. 60.10 Melting Pt. 8.5 C(1) Boiling Pt. 117.2 C(1)

Density (Condensed) 0.899(1) @ 20/4 C Density (gas) 2.07(1) Air=1 @ ______ ______

Vapor Pressure (recommended 55 C and 20 C)

10.7 mm @ 20 C(1). 53 mm @ 50 C(3) ______ @ ______

Flash Point 93 F (C.C.)(1) Autoignition Temp. ______

Flammability Limits in Air (wt %) Lower ______ Upper ______

Explosive Limits in Air (wt. %) Lower ______ Upper ______

Solubility

Cold Water miscible(2) Hot Water ______ Ethanol miscible(3)

Others: slightly soluble ether, insoluble benzene(4)

Acid, Base Properties alkaline(4)

Highly Reactive with copper and copper alloys.(2)

Compatible with aluminum, steels(2).

Shipped in Tank cars, truck, drums, carbon steel(2).

ICC Classification ______ Coast Guard Classification ______

Comments forms hydrite m.p. 10 C, bp. 118 C(5).

References (1) 0766
(2) 2298
(3) 1570
(4) 1492

HAZARDOUS WASTES PROPERTIES WORKSHEET

231

H. M. Name Isopropylamine

IUC Name 2-aminopropane

Common Names isopropylamine

Structural Formula

$(CH_3)_2CHNH_2$

Molecular Wt. 59.11 Melting Pt. -102 C(1) Boiling Pt. 31.7 C(1)

Density (Condensed) 0.694 @ 15/4 C(1) Density (gas) 2.03(3) Air=1.0 @ ______ ______

Vapor Pressure (recommended 55 C and 20 C)

______ @ ______ ______ @ ______ ______ @ ______

Flash Point -15 F(1) Autoignition Temp. 756 F(1)

Flammability Limits in Air (wt %) Lower ______ Upper ______

Explosive Limits in Air (wt. %) Lower 2.3%(1) Upper ______

Solubility

Cold Water soluble(3) Hot Water soluble(3) Ethanol soluble(3)

Others: soluble in ether(3)

Acid, Base Properties basic

Highly Reactive with ______

Compatible with ______

Shipped in Tank cars, truck, drums(2).

ICC Classification ______ Coast Guard Classification ______

Comments colorless, highly volatile, strong irritating odor(4).

References (1) 0766
(2) 0281
(3) 1570
(4) 2298

HAZARDOUS WASTES PROPERTIES WORKSHEET

265

H. M. Name Methylamine

IUC Name aminoethane

Common Names methylamine

Structural Formula

CH_3N

Molecular Wt. 31.1 Melting Pt. -93.5 C(1) Boiling Pt. -6.79 C(1)

Density (Condensed) 0.662 @ 20/4 C(1) Density (gas) 1.07(1) (Air=1) @

Vapor Pressure (recommended 55 C and 20 C)

1396 mm @ 20 C(3) 5170 mm @ 52 C(3) @

Flash Point 0 F (C.C.)(1) Autoignition Temp. 806 F(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower 4.95%(1) Upper 20.75%(1)

Solubility

Cold Water very soluble(3) Hot Water very soluble(3) Ethanol soluble

Others:

Acid, Base Properties

Highly Reactive. Corrosive to copper, copper alloys, zinc, zinc alloys, aluminum, and galvanized surfaces(3).

Compatible with

Shipped in steel tank cars, trucks, cylinders(3).

ICC Classification Coast Guard Classification

Comments colorless gas or liquid, strong ammoniacal odor(1).

References (1) 0766
(2) 1570
(3) 0281

HAZARDOUS WASTES PROPERTIES
WORKSHEET

18

H. M. Name Aminoethylethanol amine

IUC Name

Common Names 2-aminoethylethanol amine
N(2-hydroxyethyl)ethylenediamine
2-amino-2' hydroxydiethylamine

Structural Formula

$NH_2CH_2CH_2NHCH_2CH_2OH$

Molecular Wt. 104.16

Melting Pt.

Boiling Pt. 243.7(1)

Density (Condensed) 1.0304 @ 20/20(1)

Density (gas) 3.59(1) @

Vapor Pressure (recommended 55 C and 20 C)

<0.01 mm Hg @ 20 (1)

@

@

Flash Point 265 F (C.C.)(1)

Autoignition Temp. 695 F(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Combustible with non-toxic residue(2)

Solubility

Cold Water miscible(3)

Hot Water

Ethanol miscible(3)

Others: slightly soluble in benzene, ligroin(3)

Acid, Base Properties approx. neutral

Highly Reactive with can react with oxidizing materials(1), Highly flammable.(2)

Compatible with

Shipped in

ICC Classification

Coast Guard Classification

Comments

References (1) 0766
(2) 2297
(3) 1570

HAZARDOUS WASTES PROPERTIES
WORKSHEET

75

H. M. Name N-Butylamine

IUC Name 1-aminobutane

Common Names 1-aminobutane

Structural Formula

$CH_3CH_2CH_2CH_2NH_2$

Molecular Wt. 73.14 Melting Pt. -50.5 C(4) Boiling Pt. 71.8 C(4)

Density (Condensed) 0.74-0.76 @ 20/20 (1) Density (gas) 2.52(1) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point <45 F(C.C.)(1) Autoignition Temp. 594 F(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower 1.7% Upper 9.8%(1)

Combustible with non-toxic residue(2)

Solubility

Cold Water miscible(3) Hot Water Ethanol miscible(3)

Others: miscible with ether(3)

Acid, Base Properties basic

Highly Reactive with

Compatible with

Shipped in

ICC Classification Flammable liquid,red label(5) Coast Guard Classification

Comments

References (1) 0766
(2) 2297
(3) 1492
(4) 1570
(5) 2298

HAZARDOUS WASTES PROPERTIES
WORKSHEET

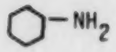
134

H. M. Name Cyclohexylamine

IUC Name aminocyclohexane

Common Names cyclohexylamine

Structural Formula



Molecular Wt. 99.18 Melting Pt. -17.7 C(1) Boiling Pt. 134.5 C(1)

Density (Condensed) .865 g/cm^3(1) @ 25/25 C Density (gas) 3.42 (1) (Air=1) @

Vapor Pressure (recommended 55 C and 20 C)

24 C @ 9.6 mm(2) 55 C @ 46 mm(2) @

Flash Point 90 F(C.C.)(1) Autoignition Temp. 560 F(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Moderate fire hazard when exposed to heat or flame(1)

Solubility

Cold Water miscible(2) Hot Water miscible(3) Ethanol miscible(2)

Others: miscible - all common organic solvents(3)

Acid, Base Properties strong base(3)

Highly Reactive with oxidizing materials(1)

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments forms azeotope with H_2O (65.8% H_2O)(2) gives off toxic fumes on decomposition(HCN)(1)

References (1) 0766
(2) 1570
(3) 1492

HAZARDOUS WASTES PROPERTIES
WORKSHEET

150

H. M. Name Diethanolamine

IUC Name 2,2'-iminodiethanol

Structural Formula

$(HOCH_2CH_2)_2NH$

Common Names Di(2-hydroxyethyl) amine(1)
diethylolamine(3),bis(hydroxyethyl)amine(4)
2,2'-dihydroxydiethylamine(3)
N-(hydroxyethyl)ethylenediamine(3)

Molecular Wt. 105.14 Melting Pt. 28 C(1) Boiling Pt. 269.1 C(decomp) 238-40 C(4)

Density (Condensed) 1.0919 @ 30/20 C(1) Density (gas) 3.65(1) @

Vapor Pressure (recommended 55 C and 20 C)

5 mm Hg @ 138 C(1) @ @

Flash Point 280 F (O.C.)(1) Autoignition Temp. 1224 F(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Combustible with non-toxic residue(2)

Solubility

Cold Water very soluble(3) Hot Water Ethanol very soluble(3)

Others: slightly soluble in ether, benzene(3), miscible in methanol, acetone(4)

Acid, Base Properties moderate base(4) pH of 0.1N aq.soln.: 11.0(4)

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 0766
(2) 2297
(3) 1570
(4) 1492

HAZARDOUS WASTES PROPERTIES
WORKSHEET

151

H. M. Name Diethylamine

IUC Name

Common Names diethylamine

Structural Formula

$(CH_3CH_2)_2NH$

Hydrate m.p - 19(5)

Molecular Wt. 73.14

Melting Pt. -48 C(4) -38.9 C(1)

Boiling Pt. 56.3 C(4) 55.5 C(1)

Density (Condensed) .710g/cc @ 20/20 C(1)

Density (gas) 2.53 (Air=1) @

Vapor Pressure (recommended 55 C and 20 C)

194 mm @ 20 C(2)

620 mm @ 50 C(2)

@

Flash Point <0 C(1)

Autoignition Temp. 594 F(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water very soluble(3)

Hot Water

Ethanol miscible(4)

Others: sol. in ether(3)

Acid, Base Properties strongly alkaline(5)

Highly Reactive with

Compatible with

Shipped in tank cars, trucks, drums(3)

ICC Classification

Coast Guard Classification

Comments colorless liquid(1)

References (1) 0766
(2) 2298
(3) 0281
(4) 1570
(5) 1492

HAZARDOUS WASTES PROPERTIES
WORKSHEET

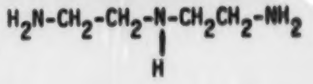
155

H. M. Name Diethylene trimine

IUC Name

Common Names 2,2'-diamindiethylamine

Structural Formula



$H_2N\text{-}CH_2\text{-}CH_2\text{-}\underset{\substack{| \\ H}}{N}\text{-}CH_2CH_2\text{-}NH_2$

Molecular Wt. 103.17 Melting Pt. -39 C(1) Boiling Pt. 208 C(1)

Density (Condensed) .9542 @ 20 C(1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

0.2 mm @ 20 C(2) 10 mm @ 86 C(2) @

Flash Point 215 F(2) Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water miscible(1) Hot Water miscible(1) Ethanol miscible(1)

Others: insoluble ether(1) soluble ligroin(1)

Acid, Base Properties basic

Highly Reactive with

Compatible with

Shipped in 1 gal tin cans; 5 and 55 gal iron drum(2).

ICC Classification None(2) Coast Guard Classification

Comments

References (1) 1570
(2) 2298

HAZARDOUS WASTES PROPERTIES
WORKSHEET

158

H. M. Name Diisopropanolamine

IUC Name

Common Names

Structural Formula

$[CH_3CH(OH)CH_2]_2$ NH

Molecular Wt. 133.19 Melting Pt. 42 C$^{(1)}$ Boiling Pt. 249 C$^{(1)}$

Density (Condensed) 0.9890 @ 45/20 C$^{(1)}$ Density (gas) 4.59$^{(1)}$ @

Vapor Pressure (recommended 55 C and 20 C)

<0.01 mm @ 20 C$^{(2)}$ 10 mm @ 133 C$^{(2)}$ 50 mm @ 167 C$^{(2)}$

Flash Point 260 F(O.C.)$^{(1)}$ Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 87% at 20 C Hot Water Ethanol miscible

Others:

Acid, Base Properties moderately basic

Highly Reactive with

Compatible with

Shipped in iron or steel containers; stainless or aluminum where lack of color is important important$^{(2)}$.

ICC Classification none Coast Guard Classification

Comments

References (1) 0766
(2) 2299

HAZARDOUS WASTES PROPERTIES
WORKSHEET

159

H. M. Name Dimethylamine

IUC Name

Common Names Dimethylamine

Structural Formula

$(CH_3)_2NH$

Molecular Wt. 45.08 Melting Pt. -92 C(1) Boiling Pt. 6.88 C(1)

Density (Condensed) 0.680 g/cc @ 0/4 C(1) Density (gas) 1.55(1) (Air=1) @

Vapor Pressure (recommended 55 C and 20 C)

2 atm @ 25 C(3) 5 atm @ 53.9 C(2) @

Flash Point 21 F (O.C.)(1) Autoignition Temp. 756 F(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower 2.8% Upper 14.4%(1)

Solubility

Cold Water very(2) Hot Water very(2) Ethanol soluble(2)

Others: soluble ether, tetrahydrofuran(2)

Acid, Base Properties basic

Highly Reactive with

Compatible with

Shipped in

ICC Classification MCA warning label flammable gas, red label Coast Guard Classification red label

Comments

References (1) 0766

(2) 1492

(3) 1570

HAZARDOUS WASTES PROPERTIES WORKSHEET

178

H. M. Name Ethylamine

IUC Name aminoethane

Common Names ethylamine, aminoethane, monoethylamine

Structural Formula

$CH_3CH_2NH_2$

Molecular Wt. 45.08 Melting Pt. -80.6 C(1) Boiling Pt. 16.6 C(1)

Density (Condensed) .706 , @ 0/4 C(1) Density (gas) 1.56(1) (Air=1) @

0.6892 @ 15/15 C(4)

Vapor Pressure (recommended 55 C and 20 C)

400 mm @ 2.0 C(1) 700 mm @ 15 C(1) 1 atm 16.6 C(4)

5 atm @ 65.3 C(4)

Flash Point <0 C(1) Autoignition Temp. 723 F(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water miscible(2) Hot Water Ethanol miscible

Others: miscible ether(2)

Acid, Base Properties alkaline(5)

Highly Reactive with

Compatible with carbon steel(2)

Shipped in carbon steel tank cars, trucks, drums(2)

ICC Classification flammable liquid, red label IATA: red label(2) Coast Guard Classification

Comments colorless liquid, strong ammoniacal odor(1).

References (1) 0766

(2) 2295

(3) 1570

(4) 1492

HAZARDOUS WASTES PROPERTIES WORKSHEET

173,279

H. M. Name Monoethanolamine

IUC Name 2-aminoethanol

Common Names 2-aminoethanol, ethanolamine β-aminoethyl alcohol, 2-hydroxyethylamine, β-hydroxyethylamine, ethylolamine, colamin.

Structural Formula

$NH_2CH_2CH_2OH$

Molecular Wt. 61.08 Freezing Pt. 10.5 C(1) Boiling Pt. 170.5 C(1)

Density (Condensed) 1.0180 @ 20/4 (1) Density (gas) 2.11(1) @

Vapor Pressure (recommended 55 C and 20 C)

6 mm Hg @ 60 C(1) @ @

Flash Point 200 F(O.C.)(1) Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water miscible(2) Hot Water Ethanol miscible(2)

Others: miscible with methanol, acetone(2).

Acid, Base Properties strong base; K (25)C = 3.39×10^{-10}; pH 25% Aq.soln: 12.1; 0.1N Aq. soln: 12.05(2).

Highly Reactive with

Compatible with

Shipped in ordinary steel containers(3).

ICC Classification Coast Guard Classification

Comments

References (1) 0766
(2) 1492

HAZARDOUS WASTES PROPERTIES WORKSHEET

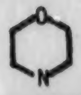
281

H. M. Name Morpholine

IUC Name

Common Names tetrahydro-2H-1,4-oxazine
tetrahydro-2,4-isoxazine
diethylene oximide

Structural Formula



Molecular Wt. 87.12 Melting Pt. -4.9 C(1) Boiling Pt. 128 C(1)

Density (Condensed) 0.9994 @ 20/4 C(1) Density (gas) 3.00(3) @

Vapor Pressure (recommended 55 C and 20 C)

10 mm @ 23 C(3) @ @

Flash Point 100 F (O.C.)(3) Autoignition Temp. 590 F(3)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water miscible(1) Hot Water Ethanol miscible(2)

Others: miscible acetone, benzene, ether, methanol, ethylene glycol, oils(2).

Acid, Base Properties strong base

Highly Reactive with

Compatible with

Shipped in

ICC Classification None Coast Guard Classification

Comments steam volatile, no H_2O azeotrope

References (1) 1570
(2) 1492
(3) 0766

HAZARDOUS WASTES PROPERTIES WORKSHEET

359

H. M. Name *n*-Propylamine

IUC Name 1-aminopropane

Common Names

Structural Formula

$CH_3CH_2CH_2NH_2$

Molecular Wt. 59.11 Melting Pt. -83 C(1) Boiling Pt. 47.8 C(1)

Density (Condensed) 0.7173 @ 20 C Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

250 mm @ 20 C(2) @ @

Flash Point -35 F(2) Autoignition Temp. 604 F(2)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower 2.0% Upper 10.4%(2)

Solubility

Cold Water soluble(1) Hot Water soluble(1) Ethanol very soluble( )

Others:

Acid, Base Properties basic

Highly Reactive with

Compatible with

Shipped in

ICC Classification IATA: Flammable liquid, red label. Coast Guard Classification

Comments

References (1) 1570

(2) 0766

HAZARDOUS WASTES PROPERTIES
WORKSHEET

441

H. M. Name Triethanolamine

IUC Name 2,2',2"-trihydroxytriethylamine

Common Names tris(hydroxyethyl)amine
trihydroxytriethylamine
2,2',2"-nitrilotriethanol

Structural Formula

$(HO\text{-}CH_2CH_2)_3N$

Molecular Wt. 149.19   Melting Pt. 21.2 C(1)   Boiling Pt. 360 C(1)

Density (Condensed) 1.1258 @ 20/20 C(1)   Density (gas) 5.14(1) @

Vapor Pressure (recommended 55 C and 20 C)

10 mm @ 205 C(1)   @   @

Flash Point 335 F(C.C.)(1)   Autoignition Temp.

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility

Cold Water miscible(3)   Hot Water miscible(3)   Ethanol miscible(3)

Others:

Acid, Base Properties basic(3)

Highly Reactive with slightly ether (1.6%), benzene (4.2%), carbon tetrachloride (0.9%), n-heptane (0.1%), ligroin, soluble chloroform, miscible acetone, methanol(3).

Compatible with

Shipped in standard iron and steel containers(4)

ICC Classification none   Coast Guard Classification

Comments very hydroscopic and viscous(3)

References (1) 0766
(2) 1570
(3) 1492
(4) 2299

HAZARDOUS WASTES PROPERTIES
WORKSHEET

442

H. M. Name Triethylamine

IUC Name

Common Names triethylamine

Structural Formula

$(CH_3CH_2)_3N$

Molecular Wt. 101.19 Melting Pt. -114.7 C(1) Boiling Pt. 89.3 C(1)

Density (Condensed) 0.7275 @ 20/4 C(1) Density (gas) 3.48 @

Vapor Pressure (recommended 55 C and 20 C)

45 mm @ 20 C(1) 210 mm @ 55 C(3) @

Flash Point 20 F (O.C.)(2) Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower 1.2% Upper 8.0%(2)

Solubility

Cold Water miscible less than 19 C(3) Hot Water slightly soluble(3) above 19 C. Ethanol miscible(3)

Others: acetone, benzene, ether(3)

Acid, Base Properties basic

Highly Reactive with

Compatible with

Shipped in

ICC Classification IATA: Flammable, red label Coast Guard Classification

Comments

References (1) 1570
(2) 0766
(3) 1492

HAZARDOUS WASTES PROPERTIES WORKSHEET

444

H. M. Name Triethylene tetramine

IUC Name

Common Names

Structural Formula

$H_2NCH_2(CH_2NHCH_2)_2CH_2NH_2$

Molecular Wt. 146.24 Melting Pt. 12 C(1) Boiling Pt. 266.7 C(1)

Density (Condensed) 0.982 @ 20 C(2) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

20 mm @ 157 C(1) <0.01 mm @ 20 C(2) @

Flash Point 290 F (O.C.)(2) Autoignition Temp. 640 F(2)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water Hot Water soluble(1) Ethanol soluble(1)

Others: acetone(1)

Acid, Base Properties basic

Highly Reactive with

Compatible with

Shipped in

ICC Classification MCA Warning label Coast Guard Classification

Comments

References (1) 1570
(2) 0766

HAZARDOUS WASTES PROPERTIES
WORKSHEET

445

H. M. Name Trimethylamine

IUC Name

Common Names

Structural Formula

$(CH_3)_3N$

Molecular Wt. 59.11 Melting Pt. -117.2 C(1) Boiling Pt. 2.87 C(1)

Density (Condensed) 0.6709 @ 0/4 C(1) Density (gas) 2.0(3) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp. 374 C(3)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %)(3) Lower 2.0% Upper 11.6%(3)

Solubility

Cold Water miscible(1) Hot Water Ethanol soluble(1)

Others: ether, benzene, toluene, chloroform(1)

Acid, Base Properties strong base, $K_b = 7.4 \times 10^{-5}$ (25 C)(2)

Highly Reactive with oxidizing materials(3)

Compatible with

Shipped in

ICC Classification Flammable, red label
IATA: Flammable gas, red label

Coast Guard Classification Red label(3)

Comments

References (1) 1570
(2) 1492
(3) 0766

448

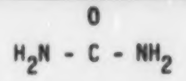
HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Urea

IUC Name

Common Names carbamide, carbonyl diamide

Structural Formula



$H_2N-\overset{O}{C}-NH_2$

Molecular Wt. 60.1 Melting Pt. 132.7 C(1) Boiling Pt. decomposes(1)

Density (Condensed) 1.335(1) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Slightly dangerous when heated to decomposition.

Solubility

Cold Water very soluble(2) Hot Water very soluble(2) Ethanol soluble(2)

Others: almost soluble in chloroform and ether(2), soluble methanol, glycerol(2).

Acid, Base Properties neutral

Highly Reactive with

Compatible with

Shipped in

ICC Classification none Coast Guard Classification

Comments no importance as an industrial hazard(1)

References (1) 0766
(2) 1492

PROFILE REPORT

Benzene Sulfonic Acid (56)

1. GENERAL

Introduction

Benzene sulfonic acid has been selected as a probable candidate for industrial disposal. Since it is different in nature from the other chemicals in this group, it is being treated separately.

Manufacture

Commercial methods of producing benzene sulfonic acid include those based on using sulfuric acid, oleum, or sulfur trioxide as sulfonating agents. Benzene is added either as a liquid or as a vapor (in excess)—the latter makes for a better acid economy. There are also processes which use a combination of these two types of hydrocarbon feed. Procedures of fairly recent origin use sulfur trioxide dissolved in sulfur dioxide (or other solvents) as a sulfonating agent and elevated temperature and pressure to increase the reaction rate and to reduce the acid consumption. Processes can be of either the batch or continuous type, though major manufacturers in this country use continuous methods.[1433]

$$C_6H_6 + H_2SO_4 \longrightarrow C_6H_5SO_3H + H_2O$$

Uses

The main use of benzene sulfonic acid is in the production of phenol. A secondary use is in the production of resorcinol. Small amounts are used in the production of benzenesulfonyl chloride and other derivatives which serve as starting materials in various organic syntheses. Minor amounts are used as catalysts in condensation, dehydration and esterification reactions.[1433]

Physical and Chemical Properties

The physical and chemical properties of the compound discussed in this report are included in the attached worksheet.

2. TOXICITY[0766,1433]

Benzene sulfonic acid is a very strong acid and as a consequence, causes acute local irritation when exposed to the skin, ingested or inhaled. Further details are unknown, except that animal experiments indicate moderate systemic toxicity and high irritation.

No Threshold Limit Value (TLV) has been established, however, it is essentially non-volatile.

3. OTHER HAZARDS

Since benzene sulfonic acid is a very strong acid, similar in many respects to sulfuric acid, dry material or aqueous solutions should not be stored or used in containers readily attacked by acid.

4. DEFINITION OF WASTE MANAGEMENT PRACTICES

Handling, Storage and Transportation

Benzene sulfonic acid is an acute local irritant to the skin, eyes and respiratory passages. The presence of moisture enhances this effect. For that reason, it should be handled in a well-ventilated area and protective clothing and respirators are recommended where dusting is a severe problem. In case of accidental contact, all contaminated clothing should be removed instantly and the skin washed thoroughly with soap and water.[0766]

Benzene sulfonic acid should be stored in a cool, dry, well-ventilated area. Opened containers should be carefully re-sealed. Containers should be checked frequently for corrosion and stock should be rotated.[0766]

Disposal

Dilute waste streams of benzene sulfonic acid are produced in its manufacture and when it is used as a raw material in the production of phenol. However, the benzene sulfonic acid is mixed with much higher concentrations of sulfuric acid in the manufacturing wastes and with phenolic and sodium sulfate wastes from the manufacture of phenol. These are best treated under the headings of sulfuric acid, sodium sulfate and phenol.

The benzene sulfonic acid content of aqueous waste streams is reduced by treatment with lime which results in a precipitate of calcium benzene sulfonate. The benzene sulfonic acid content of the water is still 0.1 - 0.2 g/l which may be too high for disposal of large quantities. The remaining acid content can be reduced by biological treatment.[1543]

Recommended air and water standards have not been established at this time.

5. EVALUATION OF WASTE MANAGEMENT PRACTICES

Option No.1 - Treatment of Aqueous Waste Streams with Lime

The benzene sulfonic acid level of aqueous waste streams can be reduced to less than 0.5 percent by treatment with lime. This effluent can be discharged directly into the municipal sewer system provided that the total daily discharge does not overload the sewage treatment plant. If this occurs, treatment as outlined on Option No.2 is necessary. Calcium benzene sulfonate is an intermediate in the production of benzene sulfonic acid and can be reprocessed.

Option No.2 - Reduction in Concentration by Biological and Chemical Degradation

In those cases where where the total quantity of benzene sulfonic acid can not be handled by the local waste water treatment plant, benzene sulfonic acid can easily be degraded biologically and chemically on site by conventional waste water treatment methods. Depending on whether or not the treatment is partial or complete, the waste water can be discharged either into the sewer or the storm drain.

Option No.3 - Incineration

Badly contaminated bulk material that can not be reclaimed, can be disposed of by incineration. The disposal or large quantities will require the use of a SO_2 scrubber.

Option No.4 - Landfill of Calcium Benzene Sulfonate

Disposal of benzene sulfonic acid can be accomplished by mixing it with a slurry of lime to form unsoluble calcium benzene sulfonate. The resulting solid has a small but significant solubility, making it readily mobile in underground water. Thus, landfill disposal represents an excessive, long-term threat to underground water supplies and must be considered much less acceptable than Option No.3 (incineration). Option No.4 is acceptable only when landfill sites are totally isolated from ground and surface water.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Most of the waste generated by the industries that produce and use benzene sulfonic acid can be handled and treated locally by incineration and conventional water treatment. Therefore, it is not considered a candidate for the National Disposal Site.

7. REFERENCES

0766 Sax, I.R., Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 1,251 p.

1433 Kirk-Othmer encyclopedia of chemical technology. 3d ed. 22 V. New York, Intercsince Publishers, 1966.

1543 Ludzack, F.J., M.B. Ettinger, Journal Water Pollution Control Federation, 32 V., 1960. p.1173-1200.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

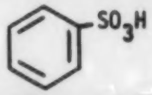
56

H. M. Name Benzene sulfonic acid

IUC Name benzene sulfonic acid

Common Names

Structural Formula



Molecular Wt. 158.18

Melting Pt. 45 C (hydrate)$^{(1)}$ 50 C$^{(2)}$

Boiling Pt.

Density (Condensed) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point

Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water soluble$^{(1)}$

Hot Water soluble$^{(1)}$

Ethanol soluble$^{(2)}$ insoluble$^{(1)}$

Others: slightly soluble benzene,$^{(1)}$ insoluble in carbon disulphide,$^{(1)}$ insoluble ether$^{(2)}$

Acid, Base Properties $K(25\ C) = 2 \times 10^{-1}$, very strong acid$^{(2)}$

Highly Reactive with

Compatible with

Shipped in

ICC Classification

Coast Guard Classification

Comments used in manufacture of phenol by fusion with NaOH

References (1) 1570
(2) 1492
(3) 0766

PROFILE REPORT

Boric Acid (60)

1. GENERAL

Introduction

Boric acid is a white crystalline solid belonging to the triclinic system. Its solubility in water is low at room temperature but is greatly increased by heating.

Boric acid reacts with various pyridine bases to form soft, white, crystalline solids, reported to be nonhygroscopic and, with the exception of the piperidine-boric acid compound, are completely hydrolyzed by dissolution in water.[1433]

In 1969, there were 138,969 tons of boric acid produced in the United States.[1751]

Manufacture

Boric acid is usually manufactured from borax or from colemanite. Granulated borax or a hot saturated solution of borax from the borax refining plant is charged into a reaction vessel. Sulfuric or hydrochloric acid, concentrated or dilute, is added until the solution is acidic. The solution is then cooled to the proper temperature, and boric acid crystals are removed by filtration. If sulfuric acid is used, the mother liquor is cooled further to recover sodium sulfate decahydrate. The crude boric acid may be refined by one or more crystallizations from water to yield purified boric acid.

When boric acid is made from colemanite, the colemanite is ground to a very fine powder and added in proportions to dilute the mother liquor and sulfuric acid at about 90 C. To prevent coating the unreacted colemanite particles with the precipitated gypsum, the slurry is stirred vigorously.

The excess acid is neutralized with lime, the iron is oxidized with permanganate, and the solution is decolorized with activated carbon and filtered. The solution is cooled to crystallize the boric acid.[1433]

Large scale commercial facilities for the manufacture of boric acid include the following:[1670]

U. S. Borax and Chemical Corporation, Des Plaines, Illinois

Ashland Chemical Company, Kansas City, Missouri

Baker Chemical Company, Charlotte, North Carolina

Uses

Boric acid has a wide variety of industrial uses. It is used in salt glazing in ceramics and in making glazes and ceramic colors. It is a raw material in making chemicals such as boron trifluoride, fluoborates, borides, and boron carbide. It is used in making boron alloys and ferroboron, which may be used for hardening steel. It is used in washing fruit to inhibit mold. It is used in cosmetics, dye stabilizers, solutions for electroplating nickel, electrolytes for electrolytic condensers, enamels, flameproofing, welding and brazing fluxes, hardening steel by heat treatment, fiber glass, optical glass, borosilicate glass, leather finishing, deliming hides and skins, latex base paints, photography, sand casting magnesium alloys, laundry starch and textile finishing, sizing, and scouring compositions.

Boric acid is used in many pharmaceutical preparations as a nonirritant, mildly antiseptic solution or in protective ointments for inflammations of the skin and mucous membranes and minor cuts and injuries.

A weak solution of boric acid has for years been a standard household remedy for washing the eyes. Boric acid is also used in hair rinses and hand lotions.[1433]

Physical and Chemical Properties

The physical and chemical properties of boric acid are included in the attached worksheet.

2. TOXICOLOGY

Boron compounds are not highly toxic and therefore are not considered to be an industrial poison. Fatal poisoning of children has been caused in some instances by the accidental substitution of boric acid for powdered milk. The medical literature reveals many instances of accidental poisoning due to boric acid, oral ingestion of borates or boric acid, and presumably absorption of boric acid from wounds and burns. The fatal dose of orally ingested boric acid for an adult is somewhat more than 15 or 20 grams and for an infant 5 to 6 grams.

Boron is one of a group of elements, such as lead, manganese and arsenic, which effects the central nervous system. It is cumulative poison and since its antiseptic value is weak, other more active and less harmful therapeutic agents should be employed for medicinal use. Boron poisoning causes depression of the circulation, persistent vomiting and diarrhea, followed by profound shock and coma. The temperature is subnormal and a scaletina from rash may cover the entire body. Boric acid intoxication can come about from absorbing toxic quantities from ointments applied to burned areas or wounds involving loss or damage to such areas of skin, but it is not absorbed from intact skin. When a 5 percent acid solution is used to irrigate body cavities most of the boric acid is absorbed by the tissues. Repeated doses can produce pathological changes in the central nervous system and kidneys.[E766]

The oral LD_{50} value to the rat is 3.5 g/kg for boric acid. The boron equivalent of this is .60 g/kg.

Rainbow trout were unaffected in a 30-minute test in 0.2 percent boric acid (350 ppm boron); in 2 percent boric acid the trout appeared distressed, but were alive after 30 minutes; after one-half hour exposure to a slurry of solid boric acid (8%), they recovered if placed in running water. The LD_{50} to 15-month old rainbow trout is 339 ppm boron for 48 hours. Safe limits are listed as 30 ppm for bass and 33 ppm for bluegill.[2358]

Boron is an essential element to plant growth but is toxic to many plants at levels as low as 1 mg/liter. The Public Health Service has established a limit of 1 mg/liter which provides a good factor of safety physiologically and also considers the domestic use of water for home gardening.[0536]

3. OTHER HAZARDS

Other than the toxic effects, boric acid presents no further problems.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, Transportation

Workers handling boric acid should wear rubber gloves and a laboratory coat.[0095]

Boric acid should be stored in containers away from any material intended for consumption by humans or animals.

Adequate procedures for the transportation of boric acid have been established by the Department of Transportation.[0278] Label requirements, as well as the maximum quantities permitted to be shipped in one outside container, are also specified.

Disposal/Reuse

United States Borax and Chemical Corporation will accept contaminated and degraded boric acid for reprocessing as long as there is a significant amount of the material to be reprocessed and it is in concentrated form.[2346]

U. S. Borax has a plant that manufacturers boric acid in Wilmington, California. The effluent from the plant contains about 3,000 ppm of boron and has been discharged directly into the ocean for many years. Although U. S. Borax plans to discontinue this practice shortly, it is claimed that the marine life around the discharge point has not been affected.

Although levels of boron as high as 3,000 ppm at the discharge point do not appear to disturb marine life when a high dilution ratio is provided, the lower limit of 1 ppm is still recommended for the safe disposal of boric acid:[0536]

Contaminant in Water	Maximum Concentration	Basis for Recommendation
Boric Acid (as Boron)	1 mg/liter	U.S. Public Health Service recommendation for domestic water

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Option No. 1 - Coagulation and Filtration.

G. Collins of U. S. Borax and Chemical Corporation claims that boric acid may be removed from aqueous waste streams by reacting the material with appropriate quantities of lime. Lime will react with boric acid to deposit calcium borates which can be filtered from solution. This will not remove all of the borate, however, as calcium borates are soluble in water to the extent of about 0.2 percent B_2O_3 (620 ppm boron). The removal of this residual amount will require more elaborate treatment methods such as ion exchange or adsorption with selected clays. The borates contained in the calcium borate sludge formed in this process are not easily recoverable, and are usually sent to Class 1 sanitary landfill areas for disposal.[2346]

Option No. 2 - Ion Exchange

Rhom and Haas offers a boron specific ion exchange resin (Amberlite XE 243) which will remove boron from solution to extremely low levels (below 1 mg/liter). Since ion exchange systems operate best with dilute solutions, this process could be used in conjunction with coagulation and filtration (discussed above) to produce an effluent with an acceptable concentration of boron. The major drawback affiliated with the use of the Rhom and Haas resin is the high operating costs involved.

Option No. 3 - Adsorption with Clays.

Selected clays might be used for the removal of borate in low concentrations. This process could be used in conjunction with coagulation and filtration to further reduce the boron concentration. Clays, however, are not specific and a large volume would be required per unit of liquor passing the clay body.[2346]

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Considering the relatively low toxicity of boric acid, and the provisions for the disposal of the major portion of waste boric acid by the producers, it is felt that boric acid does not warrant National Disposal Site treatment. The problem of small amounts of residual waste boric acid being discharged in the plant effluent is currently being solved by the manufacturers becuse of the stringent environmental regulations recently imposed. U.S. Borax, for example, will soon hook up to a new industrial sewer line that will take the combined effluents of the industries in the area to a secondary treatment plant before discharge to the ocean.

In summary, the disposal of waste boric acid is currently handled adequately at the industrial site level and this mode should be continued.

7. REFERENCES

0095. Laboratory waste disposal manual. Manufacturing Chemists Association. (Revised as of May 1970). Washington, 1970. 175 p.

0278. Code of Federal Regulations. Title 49--transportation parts 71 to 90. (Revised as of Jan. 1, 1967). Washington, U. S. Government Printing Office, 1967. 794 p.

0536. Water quality criteria. Report of the National Technical Advisory Committee to the Secretary of the Interior. Washington, Federal Water Pollution Control Administration. Apr. 1, 1968. 234 p.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corp., 1968. 1,251 p.

1433. Kirk-Othmer encyclopedia of chemical technology. 2d ed. v. 2. New York, Interscience publishers. 1966. 899 p.

1670. Chemical Week. 1972 Buyers guide issue. part 2. 109 (17):618, Oct. 1971.

2346. Personal communication. Grover Collins, U. S. Borax and Chemical Corporation to D. Dal Porto, TRW Systems, Sept. 25, 1972. Boric acid waste treatment.

2358. Sprague, R. W. The ecological significance of boron. Los Angeles, U. S. Borax and Chemical Corp., 1972. 58 p.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Boric Acid

IUC Name

Common Names Boric Acid

Structural Formula

H_3BO_3

Molecular Wt. 61.84 (1)

Melting Pt. 185 C (decomposes) (1)

Boiling Pt. .1 1/2 H_2O @ 300 C (1)

Density (Condensed) 1.435 (1) @ 15 C (1)

Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point

Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 6.35 g/100 CC (1)

Hot Water 27.6 g/100 CC (1)

Ethanol

Others: glycerine 28 g/100 CC; methyl alcohol 20.20 g/100 CC (1)

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification

Coast Guard Classification

Comments

References (1) 0766

PROFILE REPORT

Bromic Acid (64)

1. GENERAL

Bromic acid is a colorless or slightly yellow liquid that turns yellow on exposure to air. It is unstable except in dilute solutions and is almost never sold as bromic acid.[1305] Bromic acid is used as an oxidizing agent in the preparation of dyes, organic compounds, and pharmaceuticals and in the oxidation of mercaptan groups to disulfide groups in wool and hair treatment. When required, it is usually prepared for immediate use by adding sulfuric acid to barium or sodium bromate and the bromic acid recovered as an aqueous solution by subsequent distillation and absorption in water.

The limited physical/chemical properties reported for bromic acid are summarized on the attached worksheet.

2. TOXICOLOGY

Bromic acid is not highly toxic, but because it is a strong oxidizing agent it causes severe irritation of the skin, eyes and upper respiratory tract. Upon heating or standing bromic acid decomposes with liberation of bromine and oxygen. The toxicity of bromine then becomes the controlling factor (See Profile Report on Bromine [65]).

3. OTHER HAZARDS

Bromic acid produces a fire hazard on contact with organic matter. It will corrode most metals other than silver, platinum, and tantalum.[1130]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Bromic acid is handled in the same manner as any aqueous solution of a strong acid which is also a strong oxidizing agent. Contact with reducing substances is permitted only under controlled conditions.

Though bromic acid is almost never shipped it may be shipped under DOT regulations for a corrosive liquid with a White Label.

Bromic acid, because of its instability, will probably decompose to bromine and bromides on release to the environment. The recommended discharge concentrations of bromine and bromides, as listed in the Profile Reports on Bromine (65) and Hydrobromic Acid (213), are 0.1 ppm and 3 ppm respectively.[0225] The recommended provisional limits for bromine in air and water are 0.001 ppm and 0.035 ppm. The recommended provisional limits for HBr in air and water are 0.03 and 0.5 ppm.

5. EVALUATION OF CURRENT DISPOSAL PRACTICES

Option No. 1 - Reduction and Discharge

Small packaged lots of bromic acid may be decomposed by the addition of reducing materials such as sodium thiosulfate, bisulfites or ferrous salts. This method is recommended by the Manufacturing Chemists Association, but procedures for recovery of the bromides produced are not provided. Instead, when reduction is complete, the treatment solution is neutralized with soda ash, and the solution is washed down the drain with a large excess of water. This process is satisfactory for small quantities of bromic acid, but the process is not recommended for larger quantities because valuable bromides will be lost.

Option No. 2 - Reduction and Recovery as Bromide

Bromic acid, like bromine, is recovered from a dilute solution or waste stream by passing an aqueous solution over iron turnings to produce the so-called ferrosoferric bromide. This is decomposed by sodium carbonate, the excess carbon dioxide boiled off and the sodium bromide crystallized and sold.[1138]

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Bromic acid is not a candidate for National Disposal Sites because it is not stable, and therefore, requires treatment at the site where the waste originates. Option No. 2 is the process recommended for treatment of wastes containing bromic acid. This process is simple and can be performed by any plant using bromic acid.

7. REFERENCES

0095. Manufacturing Chemists Association. Laboratory waste disposal manual. 2d ed. Washington, 1969. 176 p.

0225. American Conference of Governmental Industrial Hygienists. Threshold limit values for 1971. v. 35. Occupational Hazards, Aug. 1971. p. 35-40.

1138. Jolles, Z. E. Bromine and its compounds. New York, Academic Press, 1966. 640 p.

1305. Personal communication. Mr. Sharp, Dow Chemical Company, to J. R. Denson, TRW Systems, March 16, 1972. Bromine, hydrogen bromide and bromic acid disposal.

1416. Ross, A. and E. Ross. Condensed chemical dictionary. 6th ed. New York, Reinhold Publishing Corporation, 1961. 1,256 p.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Bromic acid

IUC Name Bromic acid

Common Names

Structural Formula

$HBrO_3$

Molecular Wt. 128.92(1)   Melting Pt.   Boiling Pt. decomposes 100C(1)

Density (Condensed) 3.188 g/cc @ 20 C   Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@   @   @

Flash Point   Autoignition Temp.

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility

Cold Water completely miscile   Hot Water   Ethanol

Others:

Acid, Base Properties strong cid

Highly Reactive with Reducing sostances; bases; most metals

Compatible with Glass

Shipped to Not usually shipped

ICC Classification Corrosive liid   Coast Guard Classification corrosive liquid

Comments

References (1) 1616

PROFILE REPORT

Calcium Phosphate (95), Magnesium Oxide (247), Sulfur (413), Zinc Oxide (460), Aluminum Oxide (465), Asbestos (468), Coal (488), Vanadium Pentoxide (513)

1. GENERAL

Introduction

The inorganic materials treated in this report are part of the materials previously identified as probable candidates for municipal-type disposal. These materials are generally produced in large tonnage. They are basically nontoxic. Physically, they are all virtually insoluble in water and hence trace concentrations in water supplies would not constitute a hazard. These properties provide a common ground for the disposal of these materials. Therefore, they are discussed here as a group even though chemically, they are not a homogeneous group.

Calcium Phosphate

Calcium phosphate, $Ca_3(PO_4)_2$, occurs in nature as the minerals oxydapatite, voelicherite, and whitlockite. In pure state, it is a white, amorphous, odorless powder. The technical grade product is also known as "bone ash". Commercially, it is produced from phosphate rock which is essentially a complex salt of calcium phosphate and other calcium salts.[1492] For example, the principal mineral in the domestic phosphate rock is fluorapatite which can be expressed as $CaF_2 \cdot 3Ca_3(PO_4)_2$. By heating the phosphate rock with silica, calcium phosphate is produced as shown in the following reaction:[1662]

$$CaF_2 \cdot 3Ca_3(PO_4)_2 + H_2O + SiO_2 \xrightarrow{\Delta} 3Ca_3(PO_4)_2 + 2HF + CaSiO_3$$

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The uses of calcium phosphate are:[1492]

(1) in the manufacture of fertilizers, phosphoric acid, and other phosphorus compounds;

(2) in the manufacture of milk-glass, polishing and dental powders, porcelains, pottery;

(3) in enameling and in clarifying sugar syrups;

(4) in animal feeds;

(5) as a noncaking agent;

(6) in textile industry;

(7) as antacid for humans and animals.

Magnesium Oxide

Magnesium oxide, MgO, occurs in nature as the mineral periclase. In pure state, it is a colorless crystal of cubic form. It takes up CO_2 and moisture from air. It reacts with water to yield magnesium hydroxide. It is manufactured by calcination of magnesium carbonate or magnesium hydroxide.[1433] The oxide produced below 900 C is known as caustic-burned magnesia which can be easily hydrated with water and chemically reactive. It is used for preparation of $MgCl_2$, oxychloride cements, decolorizing agents, etc. The magnesium oxide produced above 900 C is called dead-burned or sintered magnesia which is a dense, highly refractory product used almost exclusively in the manufacture of basic refractory bricks. Magnesium oxide can also be produced economically by decomposition of magnesium chloride or magnesium sulfate. Magnesium chloride can be completely decomposed in the temperature range of 1300 to 1700 C. In 1963, the total U.S. production of magnesia was 2.8 million tons.[1433] Its uses are:[1433, 1492]

(1) in the manufacture of refractories, magnesium metal and oxychloride cements;

(2) as an ingredient in mixed fertilizers (impure grade magnesia);

(3) in the manufacture of magnesium salts;

(4) as a neutralizing agent and vulcanization accelerator in the compounding of neoprene and other rubbers (reactive grade Magnesia);

(5) as a decolorizing agent for solvents in drycleaning industry;

(6) as a absorbant and a catalyst;

(7) as an ingredient of various pharmaceutical and cosmetic formulations such as dentifrices and powders;

(8) as an antacid and laxative for man and as a laxative for young foals, calves, pigs and dogs.

Sulfur

Abundant literature has been published regarding the physical and chemical properties of sulfur, its manufacturing processes and uses. It is suffice to say that sulfur exists in several forms and occurs widely in nature, both as sulfur deposit and in various minerals. Commercially, it is produced from the well-known Frasch process and as a recovered by-product from sour natural gas, refinery gas and coal as a result of pollution control requirements. In 1967, the U.S. production of sulfur by Frasch process amounted to 7 million tons.[1433] Its uses are:[1570, 1482]

(1) in the manufacture of sulfuric acid, carbon disulfide and sulfites;

(2) in vulcanization of natural rubber;

(3) in the manufacture of black gunpowder and matches;

(4) in the manufacture of fungicide, insecticides, plastics, enamels, and metal-glass cements;

(5) in the manufacture of sulfite paper and other papers;

(6) in organic sulfur drugs and various medicinal and veterinary uses;

(7) in bleaching of dried fruits, wood pulp, straw, wool, silk, felt, and linen;

(8) in the syntheses of dyes.

Zinc Oxide

Zinc oxide, ZnO, is a white, hexagonal crystal. It occurs naturally as the mineral zincite. It is also known as flower of zinc or zinc white. Industrially, it is produced by vaporization of metallic zinc by indirect heating in the presence of CO gas and oxidation of the zinc vapor with preheated air. It may be also prepared from the zinc ore, franklinite ($ZnFe_2O_4$), or from zinc blende (ZnS). Lead blast furnace slag usually contains 10 to 18 percent zinc which can also be recovered as zinc oxide by carbon reduction process. In 1968, the U.S. production of zinc oxide was 213,826 tons.[1433] Its uses are:[1492]

(1) as a pigment in white paints;

(2) in cosmetics, driers, quick-setting cements;

(3) in dental cements (with syrupy phosphoric acid or $ZnCl_2$);

(4) in the manufacture of opaque glass and certain types of transparent glass;

(5) in the manufacture of enamels, automobile tires, white glue, matches, white printing inks, porcelains, zinc green;

(6) as an analytical chemical reagent;

(7) as an astringent, antiseptic, protective in skin diseases;

(8) in veterinary applications as dressing in moist eczema and on wounds, otorrhea in dogs.

Aluminum Oxide

Aluminum oxide, Al_2O_3, also known as alumina, occurs abundantly in nature. However, there are so many structural varieties of alumina, their properties, preparations and uses are correspondingly diversified.

Physically, it varies from the amorphous alumina gels to various crystalline forms of alumina and its hydrates. Industrially, aluminum oxide is produced from aluminum hydroxide such as bauxite. For example, α-alumina trihydrate, $Al_2O_3 \cdot 3H_2O$, is produced by the Bayer process in which the bauxite is treated with alkali, under pressure, to yield a sodium aluminate solution. The latter is decomposed by dilution and seeding with already formed alumina trihydrate. Similarly, the amorphous alumina gels can also be produced from a solution of aluminum salts or alkaline aluminates. The world consumption of alumina which is produced from about 18 million tons of bauxite, amounted to approximately 8 million tons in 1960.[1433] The uses of alumina are:[1433, 1492]

(1) as an adsorbent and desiccant for drying gases and liquids;

(2) as a catalyst for various chemical reactions such as dehydrogenation, oxidation, polymerization, petroleum cracking and reforming, etc.;

(3) as abrasives;

(4) in the manufacture of refractories;

(5) in adsorption chromatography;

(6) as filler for paints and varnishes;

(7) in the manufacture of alloys, ceramic materials, electrical insulators and resistors, dental cements, glass, artifical gems;

(8) in coating for metals.

Asbestos

Asbestos is a broad term applied to a number of fibrous mineral silicates which differ in their chemical compositions.[1433] They may be classified into two large groups:

(a) serpentine

(b) amphibole

Belonging to group (a) is the mineral chrysolite, $Mg_3Si_2O_5(OH)_4$. Group (b) contains such minerals as anthophyllite ($[Mg, Fe]_7Si_8O_{22}[OH, F]_2$), amosite (ferroanthophyllite), crocidolite, tremolite ($Ca_2Mg_5Si_{22}[OH, F]_2$), and actinolite ($Ca_2[Mg, Fe]_5Si_8O_{22}[OH, F]_2$).

In general, they are fine, slender and flexy fibers; resist fire and most solvents. Canada produces about 42 percent of the world's supply of asbestos and the United States imports about 22 percent of the world's output. In 1961, the total world production of asbestos was estimated to be 2.8 to 3.0 million tons, of which 53,000 tons were produced in the United States and 1.2 million tons in Canada. Its uses are:[1433]

(1) in the manufacture of asbestos cement products such as pipes, sheets, shingles, electrical panels, etc.;

(2) in asphalt and vinyl floor tiles;

(3) in the manufacture of asbestos papers, millboards, roofing felts, fire-proof gloves and clothing;

(4) as brake linings, clutch facings, packings, etc., in automobile industry;

(5) as an inert filter medium for filtering wine, fruit juice, beer, whisky and pharmaceuticals;

(6) in missile work, satellites, special packings for atomic energy equipment and reinforced plastics.

Coal

Voluminous publications have been lavished on coal covering every topic of interest from deposit reserves to mining and cleaning processes. It is sufficient to say that coal and steel are the two most important and basic industries in the United States. Its most important use is, of course, as a fuel. It is also used to produce coke, carbon or graphite, fuel gas, coal tar and light oils. In recent years, attempts and processes have been designed to liquefy and to gasify coal in order to circumvent the air pollution problem caused by SO_2, a product of sulfur bearing coal combustion.

Vanadium Pentoxide

Vanadium pentoxide, V_2O_5, is a yellow to red crystal of rhombic form. It is prepared by heating vanadium compound in air. Industrially, ammonium vanadate, NH_4VO_3, is carefully ignited in air to yield vanadium pentoxide. The operation is carried out in stages to lessen the chance of lower vanadium oxides being formed. It can also be prepared by slightly acidifying an alkaline, aqueous solution of ammonium vanadate. Its uses are:[1492]

(1) as a catalyst for various chemical reactions, particularly those involving oxidation such as oxidation of SO_2 and SO_3 in making sulfuric acid;

(2) in the manufacture of yellow glass, and for inhibiting ultraviolet light transmission in glass;

(3) as a developer in photography;

(4) in the manufacture of aniline black.

Sources and Types of Waste

The main sources of wastes for the materials treated in this report may include the following:

(1) manufacturers of these materials;

(2) commercial and industrial operation and processes using them as starting materials or as catalysts;

(3) users of these materials or other products containing these materials(such as paints, cosmetics, asbestos papers and boards, fertilizers, etc.);

(4) chemical laboratories and plants using these materials as chemical reagents.

The wastes are mainly of the concentrated type, because they are all insoluble in water. Most of the wastes are unused or contaminated materials or products containing these materials.

Physical and Chemical Properties

The physical and chemical properties of the materials in this report are given in the attached worksheets.

2. TOXICOLOGY[0766, 0643, 0225, 1312]

The materials discussed in this report are nontoxic in nature. However, inhalation of the solid particles could cause some physical damage.

Inhalation of fumes of freshly formed magnesium oxide may cause metal fume fever. There is no evidence however that it can produce any true systemic poisoning.

Similarly, inhalation of fresh fume of zinc oxide can cause a disease known as "brass founders' aque" or "brass chills". However, there is no cumulative effect to the inhalation of zinc fume. The zinc oxide dust which is not freshly formed is virtually innocuous. But it can block the ducts of sebaceous glands and give use to a papular, pustular eczema in men engaged in packing this compound into barrels.

Aluminum oxide is nontoxic in nature. It has been reported however that inhalation of finely divided aluminum oxide particles can cause physical damage to the lung.

Vanadium compounds act chiefly as irritants to the conjunctivae and respiratory tracts. Prolonged exposures may lead to pulmonary involvement. Responses are acute, but never chronic. Symptoms and signs of poisoning are pallor, greenish black discoloration of tongue, paroxysmal cough, conjunctivitis, dyspnea and pain in the chest, bronchitis, rales and ronchi, broncho-spasm, tremor of fingers and arms, radiographic reticulation.

Sulfur, coal, and calcium phosphate are basically nontoxic.

Inhalation of asbestos may cause a diffuse fibrosis known as asbestosis and/or cancer. The asbestosis probably begins as a "collar" about the terminal bronchiols. Usually, at least 4 to 7 years of exposure to high concentrations of asbestos dust are required before a serious degree of asbestosis results. Once established, it would continue to progress even after the exposure to asbestos dust ceases. Clinically, the most striking sign of asbestosis is the shortness of breath of gradually increasing intensity, often associated with a dry cough. In the early stages physical signs are absent or slight; in the later stages rales may be heard, and in long-standing cases there is frequently clubbing of the fingers. In the early stages of the disease a chest X-ray reveals a ground glass or granular change, chiefly in the lower lung fields. As the condition worsens, the heart outline becomes "shaggy" and regular patches of mottled shadowing may be seen. Asbestos bodies may also be found in sputum.

Although asbestos has been found to be carcinogenic, the exact causes are not yet clearly understood. The most common form of cancer caused by asbestos is the lung cancer which may appear unaccompanied by asbestosis.[0643] The latent period between exposure and evidence of carcinoma may be even longer than that for asbestosis. Another form of cancer caused by asbestos is the mesothelioma of the pleura and peritoneum. This is a very rare form of cancer which is now considered a frequent cause of death among asbestos workers.[0643] The interval between first exposure and the development of the terminal illness from mesothelioma ranged between 16 and 55 years. Finally, extrapulmonary cancer has also been reported as a cause of death among asbestos workers.

The Threshold Limit Value (TLV) recommended by the American Conference of Governmantal Industrial Hygienists (ACGIH) and the lethal doses or concentration reported are tabulated as follows:

Contaminant in Air	TLV	Lethal Dose or Concentration
Calcium Phosphate	--	--
Magnesium Oxide	15 mg/M^3 (fume)	--
Sulfur	--	--
Zinc Oxide	5 mg/M^3 (fume)	ih LC_{CA}: 2500 mg/M^3, rat
Aluminum Oxide	--	--
Asbestos	5 fibers/ml* > 5 μ in length	--
Coal	2 mq/M^3	--
Vanadium Pentoxide	0.5 mg/M^3 (dust) 0.1 mg/M^3 (fume)	--

Calcium phosphate, sulfur, and aluminum oxide are generally considered as inert or nuisance particulates when they are present as dusts in air. The proposed ACGIH TLV for these particulates is 10 mg/M^3 or 30 million particles per cubic foot, whichever is smaller.[0225]

3. OTHER HAZARDS

With the exception of sulfur and coal, all materials in this report are very stable with respect to fire and explosion hazards. Sulfur and coal are fire hazards when exposed to flame or heat. In the form of dust, sulfur and coal could cause explosion hazard when exposed to flame.

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*As determined by the membrane filter method at 430X magnification phase contrast illumination. Concentrations between 5 and 10 fibers/ml may be permitted for 15 minute periods each hour up to five times daily.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, and Transportation

The chief concern in handling and storage for the materials in this report is to maintain adequate ventilation and dust control to avoid inhalation of the fume and dust by the workers and fire and explosion hazards. For example, in the asbestos industries, the dusty air should be passed from the ventilators through fabric sleeve filters before discharged to the atmosphere. The filtration is very effective because the asbestos fibers form a mat which becomes an absolute filter. To control the asbestos in the exhaust gases, bag filters are used. Some operations are carried out in wet processes to keep the dust from becoming airborne. Dust-tight casings should be used for conveyor buckets, elevators, etc., which may be equipped with explosion relief vents, if necessary. Since sulfur and coal are combustible, they should be stored in cool and well-ventilated areas and kept away from heat, or flame, or oxidizing materials. In shipping, only sulfur is classified by the Coast Guard as a hazardous article. Dusty material like asbestos may be shipped in plastic-coated bags to prevent pollution during transportation.

Disposal/Reuse

Contaminated materials are generally disposed of rather than reprocessed for reuse. The safe disposal of these materials is here defined in terms of exposure limit as given below.

Contaminant in Air	Maximum Exposure Limit	Basis for Recommendation
Calcium Phosphate	0.1 mg/M^3 or 0.3 m.p.p.c.f.*/24 hr	0.01 TLV
Magnesium Oxide (fume)	0.15 mg/M^3/24 hr	0.01 TLV

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* Whichever is the smaller.

(Continued)

Contaminant in Air	Maximum Exposure Limit	Basis for Recommendation
Sulfur	0.1 mg/M^3 or 0.3 m.p.p.c.f.*/24 hr	0.01 TLV
Zinc Oxide (fume)	0.5 mg/M^3/24 hr	0.01 TLV
Aluminum Oxide	0.1 mg/M^3 or 0.3 m.p.p.c.f.*/24 hr	0.01 TLV
Asbestos		
Asbestos	0.05 fibers/ml > 5μ in length/24 hr	0.01 TLV
Coal	0.02 mg/M^3/24 hr	0.01 TLV
Vanadium Pentoxide (fume)	0.005 mg/M^3/24 hr	0.01 TLV
(dust)	0.001 mg/M^3/24 hr	0.01 TLV

5. EVALUATION OF WASTE DISPOSAL PRACTICES

Option No. 1 - Landfill

For the waste disposal of the materials in this report, the landfill method is recommended because the waste materials are all insoluble in water and nontoxic in nature. In fact, most of them originally come from the land as naturally-occurred minerals. Should they be washed into any water source by rainfall for instance, they can be easily removed from water by filtration. If a trace concentration of the material remains in the water supply, it would not constitute a hazard. Also, they are in general, chemically stable and will not degrade to yield air or water pollutants. The landfill method therefore offers a convenient and economic way to dispose of the waste materials.

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* Whichever is the smaller.

Option No. 2 - Incineration

Combustible materials such as coal and sulfur can also be disposed of by incineration. For coal, the combustion must be complete to insure that no carbon monoxide is produced. For sulfur and coals with high sulfur contents, the exhaust gas must be scrubbed off the sulfur dioxide formed. One convenient way to scrubb off the SO_2 is the wet limestone method. In this method, the exhaust gas is scrubbed with an aqueous suspension of finely ground limestone. This suspension usually contains an organic acid stronger than carbonic acid but weaker than sulfuric acid to accelerate the dissolution of the limestone and thereby increase the scrubbing efficiency. This method is naturally more costly than Option 1, particularly in view of the fact that pollution control of SO_2 is getting very severe.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

As landfill provides a convenient and adequate means for the disposal of the materials here, it is concluded that consideration for waste treatment at the National Disposal Site is not warranted.

7. REFERENCES

0225. American Conference of Governmental Industrial Hygienists. Threshold limit value for 1971. Occupational Hazards, Aug. 1971. p. 35-40.

0643. Sullivan, R. J. and Y. C. Athanassiadis. Air pollution aspects of asbestos. Bethesda, Maryland, Litton Systems, Inc., 1969. 105 p.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 1,251 p.

1312. Christensen, H. E., ed. Toxic substances annual list 1971. Washington, U.S. Government Printing Office, 1971. 512 p.

1433. Kirk-Othmer encyclopedia of chemical technology. 2d ed. New York, Interscience Publishers, 1966.

1492. The Merck index of chemicals and drugs. 7th ed. Rahway, New Jersey, Merck Company, Inc., 1960. 1,634 p.

1570. Weast, R. C., ed. Handbook of chemistry and physics. 48th ed. Cleveland, Chemical Rubber Company, 1969. 2,100 p.

1662. Shreve, R. N. The chemical process industries. 3d. ed. New York, McGraw-Hill, Inc., 1967. 905 p.

HAZARDOUS WASTES PROPERTIES WORKSHEET

95

H. M. Name Calcium phosphate

IUC Name

Common Names

Structural Formula

$Ca_3(PO_4)_2$

Molecular Wt. 310.18(1) Melting Pt. 1670 C(1) Boiling Pt.

Density (Condensed) 3.14(1) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.002 grams/100 ml(1) Hot Water decomposes(1) Ethanol insoluble(1)

Others: soluble in acids(1)

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

247

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Magnesium Oxide

IUC Name

Common Names

Structural Formula

MgO

Molecular Wt. 40.31(1) Melting Pt. 2800 C(1) Boiling Pt. 3600 C(1)

Density (Condensed) 3.58(1) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.00062 grams/100 ml (1) Hot Water 0.0086 grams/100 ml @ 30 C(1) Ethanol insoluble(1)

Others: soluble in acids and ammonium salts(1)

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

413

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Sulfur

IUC Name

Common Names

Structural Formula

S_8

Molecular Wt. 256.512(1)

Melting Pt. α 112.8 C (1)
β 119.0 C
γ Ca 120 C

Boiling Pt. 444.6 C(1)

Density (Condensed) α 2.07 (1)
β 1.96
γ 1.92
@

Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)(2)

1 mm Hg @ 183.8 C

@

@

Flash Point 207.2 C (2)

Autoignition Temp. 232.2 C(2)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility (1)

Cold Water insoluble

Hot Water insoluble

Ethanol slightly soluble

Others: soluble in CS_2, CCl_4

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification

Coast Guard Classification hazardous article

Comments

References (1) 1570
(2) 0766

HAZARDOUS WASTES PROPERTIES
WORKSHEET

460

H. M. Name Zinc Oxide

IUC Name

Common Names

Structural Formula

ZnO

Molecular Wt. 81.37 (1)   Melting Pt. 1975 C(1)   Boiling Pt.

Density (Condensed) 5.606(1) @   Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@   @   @

Flash Point   Autoignition Temp.

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility

Cold Water 0.00016 grams/100 ml @ 29 C (1)   Hot Water   Ethanol insoluble(1)

Others: soluble in acids, alkalis, NH_4Cl (1)

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification   Coast Guard Classification

Comments

References (1) 1570

465

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Aluminum Oxide

IUC Name

Common Names

Structural Formula

Al_2O_3

Molecular Wt. 101.96 (1)   Melting Pt. 2045 C (1)   Boiling Pt. 2980 C (1)

Density (Condensed) 3.965 @ 25 C (1)   Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@   @   @

Flash Point   Autoignition Temp.

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility

Cold Water insoluble (1)   Hot Water   Ethanol insoluble (1)

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification   Coast Guard Classification

Comments

References (1) 1570

513

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Vanadium Pentoxide

IUC Name

Common Names

Structural Formula

V_2O_5

Molecular Wt. 181.88(1)

Melting Pt. 690 C(1)

Boiling Pt. decomposes(1) @ 1750 C

Density (Condensed) 3.357(1) @

Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@

@

@

Flash Point

Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.8 grams/100 ml @ 20 C(1)

Hot Water

Ethanol insoluble(1)

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification

Coast Guard Classification

Comments

References (1) 1570

PROFILE REPORT

Carbon Disulfide (98)

1. GENERAL

Introduction

Carbon disulfide was originally selected as a probable candidate for industrial disposal. Since it is different in nature from all other chemicals in this group, it is being treated separately.

Manufacture[1433,1501]

Carbon disulfide is made by the reaction of methane with sulfur in the presence of a silica gel catalyst in a multi-stage gas phase reactor at 570 to 620 C and 20 to 30 psig. Yields based on methane are 90 to 95 percent. The major by-product, hydrogen sulfide is converted back to sulfur in a two-stage reactor. Separation from a small amount of heavy ends (mercaptans and polysulfides) is done by distillation.

Reaction:

$$CH_4 + 4S \longrightarrow CS_2 + 2H_2S$$

Regeneration of sulfur:

$$2H_2S + 2O_2 \longrightarrow 2SO_2 + 2H_2O$$

$$SO_2 + 2H_2S \longrightarrow 3S + 2H_2O$$

Some major manufacturers are:[1433, 1718]

Pittsburgh Plate Glass Co., Chemical Division
S. Charleston, W.Va.

FMC Corporation, Inorganic Chemicals Division
S. Charleston, W.Va.

Stauffer Chemical Company,
Le Moyne, Ala.
Delaware City, Del.

(2)

Uses[2336,1433]

The major use of CS_2 is as an essential ingredient in the manufacture of xanthates and xanthides. These compounds are important intermediates in the manufacture of regenerated cellulosic products, such as viscose rayon, cellophane, cellulose sponge, non-woven fabrics, and others. Xanthates and their corresponding disulfides are also used as ore flotation agents, rubber vulcanization accelerators, and chain transfer agents in the polymerization field. Other carbohydrate xanthates, such as cereal starch xanthates, impart superior strength to paper products when added during the paper-making process.

The reaction of carbon disulfide with amines leads to carbamate derivatives, some of which are potent fungicides, and others which are useful in rubber vulcanization acceleration.

Carbon disulfide is a raw material in the manufacture of carbon tetrachloride, organic mercaptans, high-purity metal sulfides, thioureas, thiocyanates, trithiocarbamates, disulfide and monosulfide organic derivatives, and rhodanines, to name but a few of the many end-products.

As a solvent, carbon disulfide is an excellent solubilizer for oils, waxes, sulfur and sulfur compounds. In mixtures with light petroleum fractions it is used for removing paraffin from pipelines and oil well casings. Extraction of vegetable oils is carried out with carbon disulfide. Absorbent clays and petroleum catalysts, used in the petroleum refining industry, can be regenerated by extraction with carbon disulfide.

Carbon disulfide, in combination with other solvents, finds use in emulsion polymerization, and as nitrocellulose and polyvinyl solvents. It is used in the recovery of sulfur ores and as a solvent in the vapor-phase curing of rubber sheets.

In the agricultural field carbon disulfide mixtures are excellent grain fumigants, soil conditioners, herbicides, rodenticides and nematocides. Carbon disulfide is also used as an insecticidal fumigant for nursery stock and for soil treatment against beetles.

Other uses for carbon disulfide include treatment of wood to improve flexural strength, corrosion inhibition and de-worming of livestock.

Physical and Chemical Properties

The physical and chemical properties of carbon disulfide are included in the attached work sheet.

2. TOXICOLOGY[0766,2336,2344]

Carbon disulfide poisoning is practically always caused by breathing its fumes (due to its volatility) although significant amounts can be absorbed through the skin. Skin contact can cause local inflammation.

The chief toxic effect is on the central nervous system, acting as a narcotic and anesthetic in acute poisoning with death following from respiratory failure. The anesthetic action is much more powerful than that of chloroform. In chronic poisoning, the effect on the nervous system is one of central and peripheral damage, which may be permanent if the damage has been severe. Sensory symptoms usually precede motor involvement. A secondary effect may be anemia.

In acute poisoning, early excitation of the central nervous system resembling alcoholic intoxication occurs, followed by depression with stupor, restlessness, unconsciousness and possibly death. If recovery occurs, the patient usually passes through the after-stage of narcosis with nausea, vomiting, headache, etc. In chronic poisoning, the picture is that of involvement of the nervous system, with neuritis and disturbance of the vision being the commonest early changes. Sensory changes such as crawling sensation of the skin, sensation of heaviness and coldness, and visual "veiling" of objects so that they appear indistinct, are noticed first. Often there is a pain in the affected parts, particularly in the limbs. These symptoms are followed by gradually increasing loss of strength. Wasting of muscles my occur. Mental symptoms vary from simple excitation or depression and irritability in the mild cases to mental deterioration, Parkinsonian paralysis and even insanity. These changes are accompanied by insomnia, loss of memory and personality changes, and chronic fatigue is a very common complaint.

The Threshold Limit Values (TLV) and Maximum Allowable Concentration (MAC) are listed as follows:

TVL	MAC
20 ppm	60 mg/M^3

3. OTHER HAZARDS

Carbon disulfide is a highly flammable, volatile liquid with a low flash point (-22 F), wide explosive range and an autoignition temperature of 100 C (212 F). Contact with exposed steam lines or the surface of an ordinary electric light bulb may cause ignition. Carbon disulfide vapor when mixed with air or oxygen in certain concentrations, is flammable and explosive.[2236] Carbon disulfide reacts violently or explosively with azides, chlorine in the presence of iron, chlorine monoxide and fluorine.[1569]

4. DEFINITION OF WASTE MANAGEMENT PRACTICES

Handling, Storage and Transportation

Due to the high degree of flammability and extreme volatility of carbon disulfide, strict ICC precautions regulate the loading, handling, transporting and labelling of containers. Non-sparking tools and hose connections must be used and the container should be grounded to prevent accumulation of static electricity. Transfer is accomplished by water padding, nitrogen displacement or pumping. Vapors should be purged from empty drums with steam while empty tank cars must have four "Dangerous Empty" placards in place.[2236,2344]

Drums and other containers of carbon disulfide should be stored in a cool, dry, and well-ventilated place away from acute fire hazards. Storage should be limited to minimize the hazard and the storage area should be of fire-resistant construction and equipped with sprinklers and/or portable fire extinguishers.[2336]

Disposal, Use, Reuse[1433,2336]

The major use (65%) of carbon disulfide is in the production of cellophane and rayon by extraction of the desired compounds as xanthites. After extraction, the carbon disulfide is regenerated and re-used.

Carbon disulfide is used as a chemical intermediate in the production of carbon tetrachloride, xanthates, xanthides and carbamates. Due to its toxicity and flammability, unreacted material is carefully recovered for re-use.

Carbon disulfide is also used as an extraction solvent for oils, waxes. sulfur, and sulfur compounds, as well as in emulsion polymerization and in the extractive regeneration of absorbent clays and petroleum catalysts. In these uses, the material is recycled indefinitely.

In the agricultural field, mixtures of carbon disulfide are used as grain fumigants, soil conditioners, herbicides, rodenticides and nematocides. This material escapes directly into the environment and cannot be recovered.

5. EVALUATION OF WASTE MANAGEMENT PRACTICES

Option No. 1 - Recycling.

The industries that use carbon disulfide as a chemical intermediate or as a solvent recycle as much material as possible. This is the method of choice, whenever possible.

Option No. 2 - Incineration

Unusable carbon disulfide solvents, as well as residues from manufacture, can be disposed of by incineration. A sulfur dioxide scrubber may be necessary if large amounts of sulfur-containing materials are being destroyed.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The wastes generated in the manufacture and use of carbon disulfide can best be handled and treated at the site of generation by incineration or recycling. Incineration should be available at the National Disposal Site where the industry generating the waste has a special problem or can not handle the specific problem safely.

7. REFERENCES

1433 Kirk-Othmer encyclopedia of chemical technology. 3d ed. 22 V. New York, Interscience Publishers, 1966.

1501 Faith, W.L., D.B. Keyes, and R.L. Clark. Industrial chemicals. 3d ed. New York, John Wiley and Sons, Inc., 1965. 824 p.

1569 Manual of hazardous chemical reactions. Boston National Fire Protection Association, 1971. 308 p.

1718 Synthetic organic chemicals, U.S. production and sales, U.S. Government Printing Office, Washington, D.C., Publication TC-479, 260 p.

2336 Technical data sheet for carbon disulfide, New York, Stauffer Chemical Company, 1964, 36 p.

2344 Carbon disulfide chemical safety data sheet, SD-12, Washington, Manufacturing Chemists Association, 1967, 16 p.

HAZARDOUS WASTES PROPERTIES WORKSHEET

98

H. M. Name Carbon disulfide

IUC Name

Common Names carbon bisulfide, dithiocarbonic anhydride

Structural Formula

CS_2

Molecular Wt. 76.14 Melting Pt. -112 C(1) Boiling Pt. 45 C(1)

Density (Condensed) 1.2628 @ 20 C(1) Density (gas) 2.67 @ 20 C(2)

Vapor Pressure (recommended 55 C and 20 C)

400 mm @ 28 C(1) 760 mm @ 46.5 C(1) @

Flash Point -30 F(2) -22 F(4) Autoignition Temp. 100 F(2)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper 50%(2,4)

Solubility

Cold Water very slightly Hot Water Ethanol miscible(1)

Others: soluble chloroform, ether, benzene, carbon tetrachloride, oils(2).

Acid, Base Properties

Highly Reactive with air when hot surface is present, azides, chlorine (in presence of iron surface)(3), oxidizing materials(4).

Compatible with iron, aluminum, glass, porcelain, teflon(2).

Shipped in

ICC Classification Flammable liquid: red label Coast Guard Classification same

Comments Ref 2 has complete data.

References (1) 1570
(2) 1492
(3) 1569
(4) 0766

PROFILE REPORT

Acridine (464), Aniline (32), 2,4-Dinitroaniline (161), *N*-Methylaniline (280), β-Naphthylamine (286), *o*-Toluidine (435), Phenylhydrazine Hydrochloride (328), Pyridine (364)

1. GENERAL

Introduction

The aromatic nitrogen-containing compounds treated in this report have been selected as probable candidates for industrial disposal because of their comparatively low toxicity and well defined methods for handling in an industrial context. These materials also share common methods for disposal and have therefore been grouped for discussion here.

Manufacture

Aniline. Aniline is produced commercially by the reduction of nitro benzene either in a continuous, vapor-phase process, by a batch solution method, or by the amination of chlorobenzene.[1433] Total U.S. production of aniline for 1970 was 398,362,000 lb.[1718, 1655]

Acridine. Acridine is one of the chief components produced commercially from coal tar. It is also readily available by a synthesis route employing the ring-closure of phenylanthranilic acid to acridone followed by reduction with zinc dust.

2,4-Dinitroaniline. 2,4-dinitroaniline is prepared by ammonolysis of 2,4-dinitrochlorobenzene.[1433] U.S. production was 196,000 lb in 1970.[1718]

N-Methylaniline. Aniline reacts with methanol in the presence of a copper-alumina catalyst to give a 96 percent yield of *N*-methylaniline.

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β-Naphthylamine. β-naphthylamine is prepared by a procedure developed by Bucherer (1904) consisting of heating β-naphthal with aqueous ammonium sulfite under pressure. The corresponding amine is obtained in excellent purity and 89 to 95 percent yield.

o-Toluidine.[1433] Toluidines are prepared by reduction of the corresponding nitrotoluenes with iron and dilute acid or by their catalytic hydrogenation.

Phenylhydrazine Hydrochloride.[1656] Aniline is converted to the diazonium salt, which in turn is reduced with a sodium sulfite to phenylhydrazine and then isolated as the hydrochloride.

Pyridine. Pyridine is a byproduct of coke production. Every ton of coal carbonized produces from 0.07 to 0.21 lb pyridine bases. The pyridine bases thus obtained consist of approximately 70 percent pyridine and 30 percent higher homologs, mainly picoline. Synthetic pyridine is produced from acetaldehyde and ammonia.[1433]

Uses

Aniline.[1433] The two most important uses of aniline are in the manufacture of dyes and rubber chemicals. Aniline is also important in the manufacture of sulfa drugs and synthetic sweetening agents.

Acridine.[1492] Used in the manufacture of dyes and intermediates. Some dyes derived from it are used as antiseptics.

2,4-Dinitroaniline.[1433] 2,4-dinitroaniline is used in the preparation of Pigment Orange (CI 12075).

N-Methylamine.[1492] Methylamine is used in tanning and in organic synthesis for the introduction of methylamine groups.

β-Naphthylamine.[1492] This material is used in the manufacture of dyes.

o-Toluidine.[1433] *o*-toluidine is used mainly as a dye intermediate to prepare Acid Red 24, Solvent Yellow 3, Solvent Red 26, Direct Red 62 and others.

Phenylhydrazine Hydrochloride.[1492] Phenylhydrazine hydrochloride is used to manufacture phenylhydrazine and as a pharmaceutical.

Pyridine. It is an intermediate in the manufacture of pharmaceuticals, textile water repellent agents, rubber chemicals, piperidine, bactericides and herbicides.[1433]

Physical and Chemical Properties

The physical and chemical properties of these aromatic nitrogen-containing compounds are included in the attached worksheets.

2. TOXICOLOGY[0766,1492]

Aromatic Amines

Aromatic amines are highly toxic but may be handled safely if proper precautions are observed. These materials can enter the body through the lungs, the gastrointestinal tract or skin. Long and continued exposure to even small amounts may produce tumors and cancer of the bladder.

The most important action of aniline on the body is the formation of methemoglobin, with the resulting anoxemia and depression of the central nervous system. In acute exposures, the signs of aniline poisoning are methemoglobinaemia and anoxemia. In less acute exposures which have been prolonged over some weeks or months, there is usually hemolysis of the red blood cells, followed by stimulation of the bone marrow and attempts at regeneration. The liver may be affected with production of jaundice. Long continued employment in the manufacture of aniline dyes has been associated with the development of papillomatous growths of the bladder, some of which became malignant. Aniline and certain other amino compounds, particularly benzidine and beta-naphthylamine, have been suspected of causing the condition.

o-Toluidine behavior is generally comparable to that of aniline. The symptoms produced by intoxication due to *o*-toluidine are headache, weakness, difficulty in breathing, air-hunger, psychic disturbances and marked irritation of the kidneys and bladder. Both *N*-methylaniline and 2,4-dinitroaniline have toxic properties similar to those of aniline.

Acridine

Acridine is strongly irritating to the skin and mucous membranes. Upon inhalation it causes sneezing, itching or even violent burning of the skin; sometimes with inflammatory swelling. It is regarded as the effective irritant in tar and creosote or pitch, which can sensitize the skin to light.

Pyridine

Chronic exposure to pyridine has been known to cause liver and kidney damage. It may cause central nervous system depression and irritation of the skin and respiratory tract. Large doses may produce gastrointestinal disturbance.

Phenylhydrazine Hydrochloride

The ingestion or subcutanous injection of phenylhydrazine has been shown to cause hemolyses of the red blood cells, an effect which has been utilized in the treatment of polycythemia. Pathological changes seen in animals exposed to phenylhydrazine hydrochloride include congestion of the spleen with hyperplasia of the reticuloendothelial system, degeneration and necrosis of the liver cells with extensive pigmentation, early damage to the tubules of the kidneys with fatty changes in the critical portion, and hyperplasia of the bone marrow.

The most common effect of occupational exposure is the development of dermatitis, which in sensitized persons may be quite severe. Systemic effects include anemia and general weakness, gastrointestinal disturbances and injury to the kidneys.

Other Hazards

In general, these materials will emit highly toxic fumes when heated to decomposition.[0766] The liquids are flammable but most can be handled with little danger of fire.[2269] Solids present only a moderate fire hazard when exposed to heat and flame.[0766]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage and Transportation

All necessary precautions must be taken to guard against health and fire hazards whenever these materials are handled. Leaking containers should be removed to the outdoors or to an isolated, well-ventilated area and promptly attended to by repairing the container or transferring the contents to a new container. Protective equipment suitable to prevent workers from coming into contact with these materials should be worn during handling. Adequate respiratory protection must be supplied in areas of poor ventilation.

Storage of these materials should be in cool, dry, and well-ventilated areas, away from acute fire hazards. It may be desirable to prevent liquids from freezing by storing them in a heated building. Small quantities should be stored in tightly closed, well labeled, approved containers to avoid leakage, spillage and careless handling as a result of ignorance of the contents.

A list of hazardous materials with packing and shipping instructions is found in Code of Federal Regulations, title 49, parts 100 to 199 (accession No. 278).

Disposal/Reuse

Contaminated or degraded materials found to be unusable in a recycling process must be disposed of in a safe manner, defined in terms of the recommended maximum concentrations released to the environment. These recommended maximum concentrations are as follows:

Contaminant in Air	Provisional Limits	Basis for Recommendation
Acridine		
Aniline	0.05 ppm (0.19 mg/M^3)/24 hrs	0.01 TLV
2,4-Dinitroaniline		
N-Methylaniline	0.02 ppm (0.09 mg/M^3)/24 hrs	0.01 TLV
β-Naphthylamine		
Phenylhydrazine HCl	0.05 ppm (0.22 mg/M^3)/24 hrs	0.01 TLV
Pyridine	0.05 ppm (0.15 mg/M^3)/24 hrs	0.01 TLV
o-Toluidine	0.05 ppm (0.22 mg/M^3)/24 hrs	0.01 TLV

Contaminant in Water and Soil	Provisional Limits
Acridine	0.95 ppm (mg/l)/24 hrs
Aniline	
2,4-dinitroaniline	
N-Methylaniline	
β-Naphthylamine	
Phenylhydrazine HCl	
Pyridine	0.75 ppm (mg/l)/24 hrs
o-Toluidine	1.10 ppm (mg/l)/24 hrs

5. EVALUATION OF CURRENT AND NEAR-FUTURE DISPOSAL PROCESSES

Option 1. Recycling of Concentrated Waste

It would be advisable in all cases to first contact the manufacturer to determine if the material can be recycled. The applicability of this option depends on the type and extent of contamination or degradation the material has suffered.

Option 2. Incineration of Concentrated and Dilute Organic Waste

In the event that it becomes necessary to dispose of a significant quantity of organic waste and purification/recycling is impractical, incineration of the materials is the recommended method of disposal. The material must be incinerated under controlled conditions whereby oxides of nitrogen are removed from the effluent gas by scrubber or a thermal device.[1435]

Option 3. Activated Slüdge Treatment of Dilute Aqueous Waste

The ability of activated sludge microorganisms to oxidize aromatic organic compounds has been demonstrated.[1044] Aromatic amines are generally considered to be biodegradable.[0534] In some cases, such as aniline and *o*-toluidine, the microorganisms must be acclimated for 24 hours before oxidation takes place.[1044] Additional research in this area is indicated for individual compounds, particularly for 2,4-dinitroaniline to assure that the subject waste is completely deactivated by biological treatment.

Option 4. Activated Carbon Treatment of Dilute Aqueous Waste[0314]

The removal of trace organic contaminants from treated waste water by absorption on activated carbon has been successfully demonstrated. This method has proven to be particularly effective in the removal of aromatic nitrogen-containing compounds which are difficult to remove by conventional biological treatment processes.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Most of the wastes generated by the industries that produce and use these materials can best be handled and treated at the site of the generation by methods discussed in Section 5. Since adequate methods are available for disposal of these materials and they can be implemented by the manufacturers and users, they are not judged to be candidates for National Disposal Sites.

7. REFERENCES

0278. Code of Federal Regulations. Title 49 -- transportation, parts 100 to 199. (Revised as of January 1, 1972). Washington, U.S. Government Printing Office, 1972. 891 p.

0314. Jones, H. R. Environmental control in the organic and petrochemical industries. Park Ridge, New Jersey, Noyes Data Corporation 1971. 257 p.

0766. Sax. N. J. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corp., 1968. 1,251 p.

1044. Marion, C. V. and George W. Maloney. Ability of activated sludge microorganisms to oxidize aromatic organic compounds. Proceeding of the 18th Industrial Waste Conference, 1963. Engineering Bulletin of Purdue University 1963. p 297-308.

1433. Kirk-Othmer encyclopedia of chemical technology. 2d ed. New York, Interscience Publishers, 1966. 899 p.

1435. John Zink Company. NO_x destructor. Bulletin No. NO_x1071m, Tulsa, John Zink Company. 1 p.

1492. The Merck index of chemicals and drugs. 7th ed. Rahway, Merck Company, Inc. 1960. 1634 p.

1655. Fieser, L. F. and M. Fieser. Organic chemistry. 3d ed. Boston, D. C. Heath and Company, 1956. 1112 p.

1656. Condon, F. E. and H. Meislich. Introduction to organic chemistry. New York, Holt, Rinehart and Winston, Inc. 1960. 841 p.

1718. United States Tariff Commission. Synthetic organic chemicals. United States production and sales, 1970. Washington, U.S. Government Printing Office, 1972. 262 p.

2269. Manufacturing Chemists' Association, Inc. Chemical safety data sheet SD-17. Properties and essential information for safe handling and use of aniline. Revised 1963, Washington, Manufacturing Chemists' Association, Inc. 14 p.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

32

H. M. Name Aniline

IUC Name

Common Names Aniline, phenylamine, aminobenzene
aniline oil, aminophen

Structural Formula

$C_6H_5NH_2$

Molecular Wt. 93.12(1) Melting Pt. 6.2 C(1) Boiling Pt. 184.4 C(1)

Density (Condensed) 1.02(1) @ 20/4 C Density (gas) 3.22(4) (to air = 1.0) @

Vapor Pressure (recommended 55 C and 20 C)

1mm @ 35 C(3) 10mm @ 70 C(3) @

Flash Point 168 F(1) Autoignition Temp. 617 C(4)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 3.9g/100 ml(4) soluble(3) Hot Water 6.4g/100 ml soluble(3) Ethanol ∞ soluble(3)

Others: ∞ in benzene(3), miscible alcohol, benzene, chloroform & most other organic solvents(4)

Acid, Base Properties basic pK_b = 9.3(4)

Highly Reactive with oxidizers(4), solutions of Fe, Zn, Al

Compatible with

Shipped in Tank cars, trucks, drums, bottles

ICC Classification Coast Guard Classification

Comments Colorless, oily liquid(1), noncorrosive(4),
Mfg(5): Allied Chemical Corp.; Am. Cyanamid Co.; E. I. du Pont de Nemours & Co., Inc.; First Chem. Corp.; Mobay Chem. Co.; Rubicon Chem., Inc.; Uniroyal, Inc.

References (1) 0766 (5) 1718
(3) 1570
(4) 2269

HAZARDOUS WASTES PROPERTIES
WORKSHEET

161

H. M. Name 2,4 - dinitroaniline

IUC Name

Common Names 2,4 - dinitrophenylamine

Structural Formula

$C_6H_5N_3O_4$

Molecular Wt. 183.12(1) Melting Pt. 187.5-188 C(1) Boiling Pt.

Density (Condensed) 1.61(5) @ 14 C(2) Density (gas) 6.31(3) @

Vapor Pressure (recommended 55 C and 20 C) (Air = 1)

@ @ @

Flash Point 435 F(C.C.)(3) Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water insoluble(1) Hot Water very slightly(1) Ethanol 18 g/100 ml(1)

Others: soluble in hot

Acid, Base Properties Neutral pk_a 18.46

Highly Reactive with Can react with oxidizing materials(3)

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments Yields toxic materials upon decomposition.
Mfg.(4): American Aniline products; American Cyanamid Co.;
Southern Dyestuff Co.

References (1) 1492 (4) 1718
(2) 1570
(3) 0766

HAZARDOUS WASTES PROPERTIES
WORKSHEET

280

H. M. Name Monomethylaniline

IUC Name

Common Names Methylphenylamine(3)
N - methylaniline(3)
LD oral rabbits: 280mg/kg(4)

Structural Formula

C_7H_9N[4]

Molecular Wt. 107.15(1) Melting Pt. -57.0 C(1) Boiling Pt. 195.7 C(1)

Density (Condensed) 0.986 @ 20/4(1) Density (gas) 3.7(1) @

Vapor Pressure (recommended 55 C and 20 C)

1mm @ 36 C(1)	10mm @ 76.2 C(2)	40mm @ 106C(2)

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water insoluble(3) Hot Water Ethanol soluble(3)

Others: soluble in ether(3), chloroform(3)

Acid, Base Properties

Highly Reactive with When heated to decomposition, it emits highly toxic fumes of aniline.(1)

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments Sources(5): American Cyanamid Co.; E. I. du Pont de Nemours & Co., Inc.

References (1) 0766 (5) 1571
(2) 1570
(3) 1492

HAZARDOUS WASTES PROPERTIES WORKSHEET

286

H. M. Name β - Naphthylamine

IUC Name 2 - aminonaphthalene(3) 2-naphthylamine(3)

Common Names

Structural Formula

$C_{10}H_9N$[3]

Molecular Wt. 143.18(1) Melting Pt. 111.5 C(1) Boiling Pt. 306.0 C(1)

Density (Condensed) 1.061 @ 98/4 C[1] Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

1 mm Hg @ 108 C(1) @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) (2) Lower Upper

Combustible with nontoxic residue

Solubility

Cold Water Hot Water volatile w/steam(3) Ethanol soluble(3)

Others: soluble in ether(3)

Acid, Base Properties

Highly Reactive with Very toxic chemical in any of its physical forms.(1)

Repeated absorption may result in bladder tumors.(3)

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments Sources:(4) Wilson Dye & Chemical Dist. Inc.; Wilson Export & Import Corp.

References (1) 0766 (4) 1571

(2) 1570

(3) 1492

HAZARDOUS WASTES PROPERTIES
WORKSHEET

328

H. M. Name Phenylhydrazine Hydrochloride

IUC Name

Common Names Phenylhydrazine Hydrochloride

Structural Formula

$C_6H_5NHNH_2HCl$

Molecular Wt. 144.6(1)   Melting Pt. 245 C(1)   Boiling Pt.

Density (Condensed) @   Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@   @   @

Flash Point   Autoignition Temp.

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility(3)

Cold Water soluble   Hot Water   Ethanol soluble

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification   Coast Guard Classification

Comments Mfg:(4) Eastern Chemical Corp.

References (1) 0766
(2) 1492
(3) 1571

HAZARDOUS WASTES PROPERTIES
WORKSHEET

364

H. M. Name Pyridine

IUC Name Azine(2)

Common Names

Structural Formula

C_5H_5N[1]

Molecular Wt. 79.10(1)

Solidif. Melting Pt. -42 C(1)

Boiling Pt. 115-116 C(1)

Density (Condensed) 0.9780 @ 25/4(1)

Density (gas) 2.73(3) @

Vapor Pressure (recommended 55 C and 20 C)

10mm Hg @ 13.2 C(3)

@

@

Flash Point 68 F(C.C.)(3)

Autoignition Temp. 900 F(3)

Flammability Limits in Air (wt %) Lower Upper

Explosive Range in Air (wt. %) Lower 1.8 Upper 12.4(3)

Solubility

Cold Water Miscible(1) Hot Water Ethanol Miscible(1)

Others: Miscible with ether(1), Petr. Ether(1), oils(1) and many other organic solvents(1)

Acid, Base Properties Weak base(1) pKa = 5.19(1)

Highly Reactive with when heated to decomposition, it emits highly toxic fumes of cyanides(3); can react vigorously with oxidizing materials.(3) Highly flammable(4) Highly explosive(4)

Compatible with Highly toxic(4)

Shipped in

ICC Classification Flammable liquid(3)

Coast Guard Classification Combustible liquid(3) Inflammable liquid(3)

Comments Sources(5): J. T. Baker Chemical Co.; Corco Chemical Corp.; Koppers Co., Inc.; Ore & Ferro Corp.; S.S.T. Corp. George UHE Co., Inc.;

References (1) 1492 (5) 1571
(2) 1570
(3) 0766

435

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name o-toluidine

IUC Name 2-aminotoluene(1)

Common Names 2-methylaniline(1)

Structural Formula

C_7H_9N

Molecular Wt. 107.16(1)

Melting Pt. α, -23.7 C(1) β, -14.7 C

Boiling Pt. 200.23 C(1)

Density (Condensed) 0.9984(1) @ 20/4

Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

1mm @ 44 C(3)

Flash Point 87 C

Autoignition Temp. 900 F(3)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility[1]

Cold Water sl. sol.(1)

Hot Water

Ethanol ∞

Others: Ether(∞), CCl_4 (∞)

Acid, Base Properties basic

Highly Reactive with Oxidizing agents(4)

Compatible with

Shipped in

ICC Classification

Coast Guard Classification

Comments Dye Manufacture(2), MAC:5 ppm in air(3), Supplier: DuPont(5)

References (1) 1570 (4) 1569

(2) 1492 (5) 1571

(3) 0766

HAZARDOUS WASTES PROPERTIES WORKSHEET

464

H. M. Name Acridine

IUC Name

Structural Formula

$C_{13}H_9N$[1]

Common Names Acridine; 2,3,5,6-dibenzopyridine(1); 10-azaanthracene[1]

Molecular Wt. 179.21(2) Melting Pt. 110 C(1) Boiling Pt. 346C(1)

Density (Condensed) 1.1005 @19.7/4C(1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

1 mm @ 129.4 C(2) 10mm @ 184.0 C(3) 40mm @ 224.2 C(3)

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility (3)

Cold Water Hot Water slightly soluble Ethanol soluble

Others: ether, benzene, CS_2

Acid, Base Properties Weak base(1)

Highly Reactive with Volatile with steam

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1492
(2) 0766
(3) 1570

PROFILE REPORTS ON THE COPPER SALTS

Copper Nitrate(121), Copper Sulfate(122)

1. GENERAL

The subject copper compounds, copper II nitrate, copper I sulfate, and copper II sulfate, are moderately poisonous materials. It is believed that only the copper II compounds, (cupric nitrate and cupric sulfate) occur as waste materials to any significant extent.

Industries, besides producers, which make these waste materials in various forms include metal plating, metal pickling, and circuit board etching. Normally waste streams that contain these compounds do not exist as pure solutions, but rather are contaminated with other inorganic and organic material. There are cases, however, in which copper sulfate occurs as a reasonably pure material. Copper sulfate wastes from pickling have the greatest volume of all sources by far and are fairly pure. Copper nitrate does find uses in electroless plating, but waste volumes from this source are relatively low.

Commercial grade copper sulfate is produced by the action of sulfuric acid on copper ores and scrap copper. The copper sulfate which is formed in the solution is transfered to settling tanks where foreign material is removed. The product solution is then filtered, evaporated, recrystallized, and finally dried. The mother liquor from evaporation/recrystallization is returned to the evaporator, thus creating no liquid waste other than spills. The sludge that is obtained from settling and filtration is dumped. The process is 99 percent efficient which indicates that waste output is approximately 1 percent of the total production.[1501] Production figures for 1963 are estimated at 40,000 tons. Thus, 400 tons per year of waste copper sulfate from production is a current estimate.

There is a significant portion of copper and copper alloy pickling firms in which the acid used for copper pickling is still being dumped.[1119] Included in this waste is an anhydrous copper sulfate sludge which can and should be easily recovered. The actual pickling tanks are rarely dumped since the copper sulfate concentration increases, with use, until saturation and it begins to precipitate out of solution. Additions of sulfuric acid replace precipitated sulfate to "sharpen up" the baths for renewed efficiency.[1121]

The manufacture of printed circuit boards creates large amounts of copper wastes. Commonly used etchants include ferric chloride, chromic acid/sulfuric acid, a family of alkaline solutions, cupric chloride and ammonium persulfate. The use of ammonium persulfate materials is decreasing in large shops due to material costs and waste treatment difficulties. The presence of the ammonium ion in spent solutions complicates the normal waste treatment process of precipitation by pH adjustment. When the waste solution is made alkaline, free ammonia is liberated. The ammonia, a noxious air pollutant, also complexes the copper in solution thereby preventing precipitation.[2347] Industrial Filters Corp. claims that additions of ferric chloride to isolated concentrates of this problem solution will break the complexes. The use of hexavalent chrome is also discouraged because of the additional chemical reduction step required in the treatment process. See the profile on the chromates (21, 22, etc.).

The large shops which are close to suppliers often have their spent solutions picked up by the supplier or have in-plant precipitation and flocculation equipment. The small or remote printed circuit board shop must rely on tank truck pick-up, private scavengers, or diluted sewer dumping. In addition, the small shop is more likely to use the chrome/sulfuric and ammonium persulfate etchants, because they have general, all around capability. However, these are the two wastes which are the most difficult to treat. The industry was characterized as having no big problem with bulk disposal of spent solutions. Their real difficulties lie with dragout and rinse waters, which can contain 20 to 100 ppm copper.[2156,2352] This rinse effluent must be reduced to levels compatible with waste water treatment plants. A large firm was noted as having an effluent output of 12,000 gal. per hour.[2352]

There are additional printed circuit board copper wastes from the electroless plating used to apply the first layer of copper on the bare composite board. Ammonium and EDTA complexed copper again present the difficult waste treatment problem in dragout described above.[2352] Small shops tend to make up these solutions, use them until they are nearly depleted, and then dump them. The larger shops can afford the analysis of the solutions and make additions required to maintain them.[2349,2350]

Metal plating is another significant contributor of copper sulfate and nitrate wastes. The primary source is dragout as the actual plating baths can be maintained indefinitely. Estimates of generated wastes range from 0.1 to 5 percent of the total copper used depending on equipment, stream segregation, shape of the plated part, etc.[2349,2350] Booz-Allen indicates that "finishing effluents from fabricated metal parts" can contain 6 to 300 ppm Cu.[1623]

Copper sulfate has enjoyed wide use as a fungicide (applied directly) but this has more or less been replaced by the Bordeaux Mixture ($Cu SO_4$ and $Ca[OH]_2$ make a flocculent copper hydroxide-calcium sulfate complex). Copper sulfate is also used in fungicides for treating wood. These uses result in small amounts of waste material in containers and preparation equipment. Consumption in agriculture has been as high as 50 percent of the total production.[1501]

Copper nitrate is a difficult compound to profile because most of the production and consumption is on a captive basis where it is made and consumed entirely within a company. Captive production is primarily for catalyst manufacture. Commercial copper nitrate is also sought as raw materials for catalyst manufacture.[2348] Most of the remainder appears to be used in metal finishing as discussed earlier. Copper nitrate is used in the preparation of a wide variety of chemicals and catalysts, many of which are made at one plant. The types and uses of these catalysts are highly proprietary and little information is available. The assumption is made that waste dissolved copper nitrate occurs in highly mixed, diverse waste streams.

2. TOXICOLOGY

The compounds of copper exhibit a general toxicity which is less severe than some of the other heavy metals. Sax describes them as being moderately toxic and says that they may cause both irreversible and reversible damage not generally severe enough to cause death and injury. However, it is also specifically stated that the ingestion of a large quantity of copper sulfate has caused vomiting, gastric pain, dizziness, exhaustion, convulsions, shock, and coma which can finally lead to death. As little as 27 grams have caused death while others have recovered after ingestions of up to 120 grams. Symptoms of nervous system, kidney, and liver damage have also been reported. Copper nitrate is not mentioned as having toxicological properties different from those exhibited by the whole class of copper compounds. The sulfate and nitrate anions, are not considered to be toxic insofar as the toxic properties of compounds containing these anions are normally attributed to that of the cation with which they are bound.[0766]

The Public Health Service indicates that copper in small amounts is generally regarded as nontoxic and is in fact considered essential for human metabolism. In 1942 the maximum permissible concentration of copper in drinking water was raised from 0.2 mg/l to 3.0 mg/l. However, since it does contribute to an undesirable taste, the Public Health Service has recommended a maximum concentration of 1.0 mg/l.[1752] The critical concentration for fish has been established at 0.15 to 0.18 ppm.

Copper sulfate has also been used extensively as a fungicide and its general toxicity towards plants is significant. It has also been established that high concentrations of copper in waste streams will seriously impair the microorganisms that are employed in secondary water treatment processes. For this reason, large scale dumping of dissolved copper in the municipal sewer lines is discouraged by sewage treatment authorities.

3. OTHER HAZARDS

No flammable explosive, or other hazard has been found to exist for these compounds.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Since it is apparent that waste copper compounds can create serious problems with plant and animal life in sewer systems and open waterways, it is necessary to define waste management techniques which will minimize these hazards. Plants and processes must be designed so that no untreated wastes reach open waterways or contaminate the surroundings. Each firm should have the facilities to treat and recover copper from waste streams and temporarily hold any treatment products for ultimate disposal. If a firm is permitted to discharge to municipal sewer systems, suitable holding or pretreatment tanks are required on the plant premises.

Dried waste materials containing copper sulfate or copper nitrate can be packed, stored, and otherwise handled as if one were handling the pure compound itself. Barrels, drums, bags, boxes, and bottles can all be used to store and ship these materials. Protective clothing such as aprons. gloves, and eyewear should be worn to prevent contact with these wastes. All DOT regulations should be followed when shipping or otherwise handling these compounds.

All personnel and supervisory staff who work with these materials should be carefully educated as to the precautions that must be taken to prevent hazardous exposure.

Disposal/Reuse

The recommended maximum level of discharge for copper bearing waste to open waterways is 1.0 mg/l (ppm). This is in agreement with U.S. Public Health Service recommendations for drinking water.[1752] The proper levels of copper waste discharge to municipal sewage systems or cooperative industrial waste treatment would of course vary with such parameters as waste water volume, efficiency of the plant, etc. The Threshold Limit Value (TLV) for copper in the air is 1 mg per cubic meter.[0225]

Copper sulfate and copper nitrate both have inherent value when present as concentrates in wastes. Very large amounts of copper sulfate are produced from the numerous copper and copper alloy pickling processes that are carried out in the nation. Waste copper nitrate normally occurs in dilute solutions and is not as strong a candidate for recovery and reuse as copper sulfate. The same is true with any dilute copper waste solutions. However, with increased utilization of solution concentrating equipment, along with waste stream segregation, some dilute copper solutions are being economically recovered. The various means by which solutions can be concentrated and waste copper compounds recovered are discussed later.

5. EVALUATION OF CURRENT WASTE MANAGEMENT PRACTICES

There are two basic waste management practices which involve copper sulfate and copper nitrate. The first method, product recovery, is used primarily in industries where the waste can be kept pure through segregation and concentration. The other basic waste management option is that of destructive precipitation. This involves either pH adjustment or discharge to sewers.

Option No. 1 - Recovery of Copper Process Byproducts

Since copper sulfate has inherent value as a chemical commodity (80 to 90 cents per pound for purified grades) it is advantageous for the metal finisher to attempt recovery if it is economically feasible. There are several approaches by which valuable copper or copper compounds can be recovered.

As previously described with copper pickling, copper oxide removal continues until the pickling bath becomes saturated with copper sulfate and it settles out of the pickling solution. This nearly pure copper sulfate can be mechanically removed from the tanks, packaged and sent to a commercial reclaiming firm.

There are also in-plant processes for recovering copper metal from pickling solutions. An example of an integrated recovery and waste treatment system is described by Lancy and Pinner who have installed an electrolytic copper removal unit through which is pumped the sulfuric acid pickling solutions. Copper metal is electrolytically plated out thereby regenerating the sulfuric acid to be returned to the pickling tanks. The system is said to be simple to operate and can be easily automated.[1119]

Copper sulfate and copper nitrate waste solutions that are generated by the metal plating processes are nearly always dilute solutions (less than 500 ppm copper). Any type of copper recovery process for these dilute solutions will likely require some type of solution concentrating equipment. The addition of this type of equipment is costly, but if the value of chemicals being lost from large volume shops is larger than the cost of installing and operating recovery equipment, then such an approach is justified. The types of process which might be considered for concentrating a dilute but pure waste stream include reverse osmosis, ion exchange, dialysis, and multiple effect evaporators. The solutions can be concentrated to a point where electrolytic or other copper recovery can be carried out. Alternatively, the concentrates can be returned to plating baths, etc. or sent to a reclaiming firm.

Option No. 2 - Precipitation by pH Adjustment

Precipitation is most suitable for dilute mixed streams where copper will not be recovered for reuse. Soda ash, caustic or other alkaline chemicals can be added to copper bearing solutions to adjust the pH to about 9.5. This precipitates copper as an insoluble hydroxide gel along with the precipitates of other heavy metals which might be present in a mixed solution. Alum or other suitable floccuating agents can also be used to speed up settling, and clarification of the effluent. The treated effluent has characteristic heavy metal levels of 0 to 5 ppm. The alkaline effluent is neutralized before sewering and the resultant sludge is almost always landfilled. This procedure can be carried out in either batch or continuous processes. Turn key equipment systems are available for performing the precipitation on an automated or semi-automated basis.

There are two major disadvantages for using this procedure. The first is the problem of handling and disposing of the highly hydrated metal hydroxide sludges. It is not unusual for these sludges to contain upwards of 75 to 80 percent water by volume. Precipitation and settling is normally slow and it is necessary to have settling ponds in which to allow the coagulation process to occur. The second major disadvantage of precipitation methods is that no feasible process has yet been developed for the recovery of chemical or metal credits from this type of precipitated waste. The sludge often contains many other organic and inorganic materials which are present in the waste stream before treatment and these hinder effective purification and recovery. These mixed sludges can serve no useful purpose and can only be ultimately disposed. The method is adequate when the pH is made high enough to leave only low ppm traces of pollutants in the effluent. The ultimate disposal of the sludges is discussed later.

Option No. 3 - Dilute Discharge to Municipal Sewers

Much of the major metal finishing industry is located in highly industrial and large metropolitan areas. Significant amounts of copper waste solutions generated in pickling, plating and other related industries are being discharged to existing municipal sewage treatment.[0087,1601] The only pretreatment which is customarily given metal finishing wastes before discharge into municipal sewers is neutralization. If the material being discharged is of a considerable quantity, or if the discharge point is close to the sewage treatment plant, it is necessary to closely monitor the discharge to ensure that there will be no undersirable ill effects on the sewage stream.

When discharged to sewers, most of the copper ion will precipitate when it reacts with the sulfides that are found in normal domestic streams. This precipitation occurs in transit to the waste treatment plant and the solids are removed at the primary screening and settling facilities or after secondary biological treatment processes. This method of disposal is considerably widespread and may be considered environmentally acceptable only if the waste water treatment plants receiving these discharges can efficiently deal with the waste loads. In spite of the increased emphasis on recovery and recycling of wastes with value, the trend for using municipal sewers for industrial discharge is actually increasing.

Ultimate Disposal of Sludges from Options 2 and 3

Three ultimate disposal options for these sludges are: (1) landfill, (2) incineration, and (3) ocean disposal. Landfill is believed to be, by far, the most prevalent final disposal procedure but the problem of potential contamination of surrounding land or water tables, due to the leaching of poisonous materials from the sludge, must be considered Incineration reduces the sludge to an ash residue which can be more easily handled for ultimate disposal but at the same time could also lead to the formation of poisonous, soluble metal oxides. Incineration also requires additional equipment and a combustible fuel source as well as equipment for air pollution control. Ocean disposal is currently being practiced to a considerable degree by municipal waste treatment plants located near the coast where the primary and secondary sludges can be either pumped or barged out to submarine disposal areas. This disposal approach has been the subject of much recent debate and it is likely that it will not long remain one of the significant sludge disposal options.

Summary of Available Waste Management Options

Recovery	Waste copper is a valuable commodity and can be easily recovered.
Precipitation by pH adjustment	Best method for dilute streams, mixed streams, or other cases where recovery is not practical.
Dilute discharge to municipal sewers	Adequate for dilute streams or mixtures only if treatment facilities can operate to meet local discharge standards.

6. APPLICABILITY TOWARDS NATIONAL DISPOSAL SITES

The installation of waste treating equipment specifically for copper sulfate and copper nitrate is not recommended for National Disposal Sites for the following reasons: (1) the inherent value of copper and its compounds has led a large proportion of the firms handling these materials to install the various types of copper recovery equipment; and (2) the transport of huge volumes of non-recyclable dilute solutions is simply too expensive. Industry will continue to treat the dilute wastes by destructive precipitation, or discharge to municipal sewers.

As stated in other Profile Reports, it is very likely that a general facility for pH adjustment and precipitation will be required to handle the waste streams generated within the site itself. This same facility could also be used to treat various heavy metal wastes which might occasionally be sent to the site. These would include waste mixtures containing chromium, zinc, nickel, lead, mercury, copper and other metals.

7. REFERENCES

0225. Threshold limit values for 1971. Occupational Hazards, Aug. 1971, p. 35-41.

0766. Sax, N. I., Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corp., 1968. 1,251 p.

1119. Ceresa, M., L. E. Lancy. Metal finishing waste disposal. Metal Finishing (3 parts) 66(4): 56-62; 66(5): 60-65; 66(6):112-118; Apr., May, June 1968

1121. Lancy, L. E., R. Pinner. Waste treatment and metal recovery in copper and copper alloy pickling plant. Metallurgia 73(437)119-122; Mar. 1966

1501. Faith, W. L., D. B. Keyes, and R. L. Clark. Industrial chemicals. 3d ed. New York, John Wiley and Sons, Inc., 1965. 824 p.

1570. Weast, R. C., ed. Handbook of chemistry and physics. 48th ed. Cleveland, Chemical Rubber Company, 1969. 2,100 p.

1752. Public health drinking water standards. U. S. Department of Health Education and Welfare, Public Health Service Publication No. 956, Environmental Control Administration, Rockville, Maryland 1962.

2156. Graham, A. K., ed. Electroplating engineering handbook, 2d ed., New York, Reinhold Publishing Corp., 1962. 774 p.

2347. Personal communication. Fred Stewart, Lancy Labs, to J. F. Clausen, TRW Systems, Sept. 15, 1972.

2348. Personal communication. W. Witzleben, Allied Chemical Co., to J. F. Clausen, TRW Systems, Sept. 28, 1972.

2349. Personal communication. Simon Gary, Scientific Control Labs, to J. F. Clausen, TRW Systems, Sept. 26, 1972.

2350. Personal communication. Don Hutchinson, Harshaw Chemical Co., to J. F. Clausen, TRW Systems, Sept. 26, 1972.

2352. Personal communication. Frank Gorman, Cinch-Graphik Inc., to J. F. Clausen, TRW Systems, Sept. 29, 1972.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Copper sulfate

IUC Name Copper II sulfate pentahydrate

Common Names Blue Vitriol, Chalcanthite(1)

Structural Formula

$CaSO_4 \cdot 5H_2O$

Molecular Wt. 249.68(1)   Melting Pt. $-4H_2O$ at 110C(1)   Boiling Pt. $-5H_2O$ at 150 C(1)

Density (Condensed) 2.284 @ --   Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@   @   @

Flash Point   Autoignition Temp.

Flammability Limits in Air (wt %)   Lower none   Upper none

Explosive Limits in Air (wt. %)   Lower none   Upper none

Solubility

Cold Water 31.6g/100 cc at 0 C(1)   Hot Water 203.3 g/100cc at 100 C(1)   Ethanol insoluble

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in Barrels, drums, boxes, bags, bottles

ICC Classification No label required(2)   Coast Guard Classification

Comments

References (1) 1570

(2) 0766

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Copper nitrate

IUC Name Copper II Nitrate, trihydrate

Common Names

Structural Formula

$Cu(NO_3)_2 \cdot 3H_2O$

Molecular Wt. 241.60(1) Melting Pt. 114.5 C(1) Boiling Pt. $-HNO_3$ at 170 C

Density (Condensed) 2.32 g/cc(1) @ 25 C(1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 137.8 g/100 cc at 0 C(1) Hot Water 1270 g/100cc at 100 C(1) Ethanol 100 g/100 cc at 125 C(1)

Others: very soluble in liquid NH_3

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570
(2) 0766

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Copper Nitrate

IUC Name Copper II Nitrate, hexahydrate

Common Names

Structural Formula

$Cu(NO_3)_2 \cdot 6H_2O$

Molecular Wt. 295.64(1) Melting Pt. $-3H_2O$ at 26.4 C(1) Boiling Pt. N/A

Density (Condensed) 2.074 g/cc(1) @ N/A Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 243.7 g/100 cc at 0 C(1) Hot Water infinite(1) Ethanol soluble

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

PROFILE REPORT

Lead Oxides (242)

1. GENERAL

Introduction

Lead forms a number of oxides. There are the monoxide (PbO), the dioxide (PbO_2), the sesquioxide (Pb_2O_3), the tetroxide (Pb_3O_4), and the suboxide (Pb_2O). They are all insoluble in water. With the exception of the monoxide, they decompose upon heating to elevated temperatures and therefore possess no true melting point. Absorbed into the body, they cause the well-known lead poisoning. Since only the monoxide and the tetroxide are of industrial importance, the discussion in this report will be focused upon these two oxides.

Lead Monoxide[1433]

Lead monoxide, PbO, also called plumbous oxide, exists in two polymorphic forms; the tetragonal reddish crystal, α-PbO or litharge, and the orthorhombic yellow crystal, β-PbO or massicot. Commercially, litharge and tetraethyl lead are the two most important lead compounds. The lead monoxide is produced in large tonnage by many different processes to suit specific applications. Four major manufacturing processes based on furnace techniques are in use.

(1) Metallic lead is partially oxidized and milled to a powder (called the black oxide in trade) which is charged into a reverberatory furnace at about 600 C to complete the oxidation to yield the ordinary "chemical" litharge.

(2) Pig lead is oxidized and stirred in a reverberatory furnace or rotary kiln directly to form the lead monoxide.

(3) Molten lead is run into a cupelling furnace held at about 1000 C and molten litharge is produced.

(4) Molten lead at about 500 C is atomized into a flame where it burns vigorously to yield "sublimed" or "fumed" litharge.

In all cases the product must be cooled quickly to below 300 C to avoid the formation of red lead, Pb_3O_4. In 1965, about 105,000 tons of litharge were produced in the United States. Its main uses are:

(1) in the preparation of storage battery plates (for this purpose, the partially oxidized powder, the black oxide, is more widely used than the fully oxidized product);

(2) in the ceramics industry for the manufacture of certain glasses, glazes, and vitreous enamels, and as a flux for painting of porcelain and glass;

(3) as an activator in rubber compounding;

(4) as a raw material for producing other lead compounds;

(5) in oil refining to convert the mercaptans to less evil-smelling disulfides;

(6) as a drier in varnishes;

(7) as a yellow pigment.

Lead Tetroxide[1433]

Lead tetroxide, Pb_3O_4, also known as red lead or minium, is a bright red heavy powder. In sales, it is the second most important lead oxide. In 1965, about 30,000 tons were produced in the United States. It is produced by heating the lead monoxide in a reverberatory furnace in presence of air at 450 to 500 C until the desired Pb_3O_4 content has been reached. Its major uses are:

(1) in the manufacture of storage battery plates;

(2) as a pigment in paints for protecting metal surface against corrosion and rust.

Other uses are:

1. in glass and ceramics industries;
2. in the manufacture of lead dioxide and matches;[1492]
3. as a preferred raw material for making hard ferrites ($PbO \cdot 6Fe_2O_3$) which are finding rapidly expanding use as permanent magnets.

Other Lead Oxides[1433]

Lead dioxide, PbO_2, is a brown to black tetragonal crystal. It decomposes to lower oxides upon heating to 300 C or above. It is produced by anodic electrodeposition from solutions of lead salts or from lead monoxide or red lead used anodically. It is sold commercially in relatively small tonnage for use in high-voltage lightning arrestors and as an oxidizing agent in dye and chemical industries.

Lead sesquioxide, Pb_2O_3, is a black monoclinic crystal formed by hydrothermal decomposition of lead dioxide at 350 C. It has no commercial importance.

Sources and Types of Wastes

The lead oxides wastes may come from the following major sources:

1. manufacturers of lead oxides and other lead compounds using the lead oxides as raw materials;
2. storage battery producers and users;
3. formulators and consumers of paints containing lead oxides;
4. industrial plants for rubber compounding, glass and ceramics manufacturing;
5. users of products containing lead oxides such as lead glasses, certain insecticides and ceramic products, etc.

The lead oxide wastes are of the concentrated type and may include the unused or contaminated lead oxides or products containing lead oxides.

Physical and Chemical Properties

The physical and chemical properties of the lead monoxide and tetroxide are given in the attached worksheets.

2. TOXICOLOGY[0766]

Lead poisoning or plumbism is one of the oldest and best known of all occupational hazards. It is caused by (1) inhalation of dusts, fumes, mists or vapors; (2) ingestion of lead compounds; and (3) absorption through the skin. However, there is no evidence that inorganic lead compounds can be absorbed through the skin in sufficient quantities to cause lead poisoning. When lead is ingested, much of it passes through the body unabsorbed, and is eliminated in the feces. The greater portion of the lead that is absorbed is caught by the liver and excreted, in part, in the bile. For this reason, larger amounts of lead are necessary to cause poisoning by the route of ingestion and a longer period of exposure is usually needed to produce the poisoning symptoms. On the other hand, when the lead is inhaled, absorption takes place easily from the respiratory tract and symptoms tend to develop more quickly. So, from the standpoint of industrial safety, inhalation of lead or lead compounds is much more important and requires more serious attention than ingestion and skin absorption of lead compounds.

Lead is a cumulative poison. Increasing amounts of lead could build up in the body. The symptoms of lead poisoning may be classified according to their clinical picture as (1) alimentary; (2) neuromotor: and (3) encephalic. The alimentary type occurs most frequently. It is characterized by abdominal discomfort or pain, constipation and/or diarrhea, nausea and vomiting, joint and muscular pains, headache and dizziness. In the neuromuscular type, the chief complaints are weakness, frequently of the extensor muscles of the wrist and hand. Joint and muscular pains are more severe. Gastroenteric symptoms are present, but not as severe. Headache, dizziness and insomnia are frequently prominent. The lead encephalopathy is the most severe but the rarest manifestation of lead poisoning. It is caused by rapid and heavy lead absorption. It begins abruptly and is characterized by signs of cerebral and meningeal involvement. There is usually stupor, progressing to coma, with or without convulsion, and often terminating in death.

For treatment of lead poisoning, it has been found that the chelating agent, calcium ethylenediaminetetracetate (Ca EDTA), and related compounds are highly efficacious in removing absorbed lead from the body tissues. Ca EDTA is effective only when administered intravenously.

The Threshold Limit Value (TLV) for lead in air recommended by the American Conference of Governmental Industrial Hygienists, 1971, is 0.15 mg/M^3.[0225] The lethal doses reported for the lead oxides are given below.[1312]

(1) lead monoxide
    ip LD_{50}: 400 mg/kg, rat

(2) lead tetroxide
    ip LD_{50}: 200 mg/kg, rat

The U.S. Public Health Service has established the limits and ranges of lead concentrations in public water affecting human health as follows:[1752]

(1) Physiologically safe:

Lifetime	0.05 mg/l
Short period, a few weeks	2-4 mg/l

(2) Harmful range:

Borderline	2-4 mg/l for three months
Toxic	8-10 mg/l for several weeks
Lethal	Unknown, but probably more than 15 mg/l for several weeks

Lead in soft water is highly toxic to certain fish; 0.1 mg/l is toxic to small sticklebacks; larger fish are somewhat less susceptible to lead poisoning.

3. OTHER HAZARDS

Lead tetroxide is an oxidizing agent. It would cause slight fire hazard by chemical reaction with reducing agents. Similarly, lead dioxide would react with a reducing agent. It may also ignite some organic materials when mixed. When heated to decomposition, it emits the highly toxic fume of lead.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, and Transportation

Since lead poisoning is caused more easily by inhalation than by ingestion, adequate ventilation and dust control must be maintained to minimize the hazard of lead poisoning. Avoid breathing the lead oxide dust in handling. Wearing the dust mask approved by the U.S. Bureau of Mines for this purpose is recommended. In storage, the lead oxides should be kept away from feed or food products. As lead tetroxide is an oxidizing agent, it should also be kept away from any reducing agent to avoid fire hazard caused by chemical reactions. The lead oxides are stable chemicals under ordinary temperatures. There is no specific requirement in transportation.

Disposal/Reuse

The lead oxides (litharge and red lead) are produced in large tonnage but at a very small profit margin.[1433] Therefore, it is not economically feasible to reprocess the waste materials for reuse purpose under present circumstances. Instead, disposal of these waste materials should be of primary interest. Safe disposal of lead oxide wastes is defined in terms of maximum exposure limit as tabulated below:

Contaminant in Air	Maximum Exposure Limit	Basis for Recommendation
Lead Monoxide	0.0015 mg/M^3/24 hr	0.01 TLV
Lead Tetroxide	0.0015 mg/M^3/24 hr	0.01 TLV

Contaminant in Water	Maximum Exposure Limit	Basis for Recommendation
Lead Monoxide	0.05 mg as Pb/l	U.S. Public Health Service, Drinking Water Standards
Lead Tetroxide	0.05 mg as Pb/l	U.S. Public Health Service, Drinking Water Standards

5. EVALUATION OF WASTE DISPOSAL PROCESSES

Option No. 1 - Landfill

Since the lead oxides are insoluble in water, and also are very stable under ordinary temperatures, disposal of lead oxide wastes by means of landfill is acceptable. Mixed wastes of lead oxides such as paints, glass and ceramic products, generally do not contain any water-soluble toxic components. Hence, the risk of contaminating the ground and surface waters by these waste materials is very minimal.

Option No. 2 - Conversion to Sulfide

Contaminated lead oxide wastes can be treated with nitric acid to form nitrate which is then converted to lead sulfide by hydrogen sulfide.[0095] The sulfide precipitate can be removed by filtration and sent to lead smelter to recover its lead content.

Option No. 3 - Conversion to Carbonate

Similar to Option No. 2, the contaminated solid waste can be treated with nitric acid to yield the nitrate which is converted to lead carbonate by ammonium carbonate. The insoluble carbonate is removed by filtration and its lead content could be recovered by smelting.

In summary, the most practical method for disposal of lead oxide wastes is by landfill. However, should it be desirable or economically advantageous to recover the lead content, the waste material can be converted to lead sulfide or carbonate from which the lead content can be recovered by the smelting process.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Since the lead oxide wastes can be conveniently disposed of by landfill or by simple chemical treatment to recover the lead content, it is concluded that consideration for disposal of these waste materials at the National Disposal Site is not warranted.

7. REFERENCES

0095. Manufacturing Chemists Association. Laboratory waste disposal manual (revised May, 1970). Washington, Manufacturing Chemists Association, 1970. 176 p.

0225. American Conference of Governmental Industrial Hygienists. Threshold limit values for 1971. Occupational Hazards, p. 35-40, Aug. 1971.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 1,251 p.

1312. Christense, H. E., ed. Toxic substances annual list 1971. Washington, U.S. Government Printing Office, 1971. 512 p.

1433. Kirk-Othmer encyclopedia of chemical technology. 2d ed. New York, Interscience Publishers, 1966.

1492. The Merck index of chemicals and drugs. 7th ed. Rahway, New Jersey, Merck Company, Inc., 1960. 1,634 p.

1570. Weast, R. C., ed. Handbook of chemistry and physics. 48th ed. Cleveland, Ohio, Chemical Rubber Company, 1969. 2,100 p.

1752. Public Health Service. Drinking water standards, 1962. Washington, U.S. Department of Health, Education, and Welfare, 1969.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Lead Monoxide

IUC Name

Common Names

Structural Formula

PbO

Molecular Wt. 233.19(1) Melting Pt. 888 C(1) Boiling Pt.

Density (Condensed) 9.53(1) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.0017 grams/100 ml @ 20 C(1) Hot Water Ethanol

Others: soluble in HNO_3, alkali, lead acetate. (1)

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Lead Tetroxide

IUC Name

Common Names

Structural Formula

Pb_3O_4

Molecular Wt. 685.57(1) Melting Pt. decomposes at 500 C(1) Boiling Pt.

Density (Condensed) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility(1)

Cold Water insoluble Hot Water insoluble Ethanol insoluble

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

PROFILE REPORT

Lewisite (243)

1. GENERAL

Lewisite was manufactured and stored during World War II as a chemical warfare agent. The lewisite as manufactured was unstable, and most of the unused stock (about 150 tons) was destroyed by ocean dumping.

Lewisite is a lethal chemical warfare agent that acts as a vesicant, as a contact systemic poison, and as an inhalation and eye poison. Lewisite is no longer considered an important chemical warfare agent by the American military authorities, since there are now more effective chemical warfare agents with substantitally better physical and chemical properties. It is relatively easy and cheap to manufacture which may make its manufacture attractive to underdeveloped countries.

Lewisite is manufactured by adding acetylene to a mixture of arsenic (III) chloride and a catalyst of either aluminum chloride, mercuric chloride or cuprous chloride with strong agitation. The reaction temperature is maintained below 50 C. After completion of the reaction, the oily liquid product is treated with hydrochloric acid or ethanolamine hydrochloride and distilled. The lewisite product contains both the cis- and trans- forms of 2-chloroethenyl dichloroarsine.[0778]

The physical/chemical properties for the cis- and trans- forms of lewisite are summarized on the attached worksheets. The physical/chemical properties for the cis- and trans- forms of lewisite are summarized on the attached worksheet.

2. TOXICOLOGY

Lewisite as noted above is a skin-damaging warfare agent that acts not only as a contact poison, but also as an inhalation and eye poison. The skin-damaging effect takes place immediately. Erythemata form on the surface of the skin with doses of about 0.05 to 0.1 mg per square centimeter of skin surface. Concentrations of 0.2 mg per square centimeter positively lead to blister formation. Blisters on the surface of the skin are caused by gaseous lewisite after about 15 minutes dermal exposure to concentrations of 10 mg/l. Inhalalation of concentrations of 0.05 mg/l for 30 minutes or 0.5 mg/l for 5 minutes is considered lethal. An inhalation exposure of 0.05 mg/l for 15 minutes produces severe intoxication which causes a combat incapacity for several weeks. A lower concentration of 0.01 mg/l causes inflamation of the eyes and swelling of the lid after 15 minutes.[0778] British Anti-Lewisite (BAL, or dimercapto-1-propanol) is a specific antiodte for lewisite contact and systematic poisoning.

3. OTHER HAZARDS

Lewisite has the power to penetrate protective materials such as leather, rubber, wood, textiles, and cause damage to the enclosed skin area.[0778]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

When stored for long periods, lewisite tends to decompose. The decomposition is accelerated by traces of acid. In the presence of iron, lewisite is catalytically converted into the secondary and tertiary arsines. However, stainless steel can usually be used with lewisite. Aluminum and aluminun alloys are corroded by lewisite. Storage of lewisite in bombs and shells is possible because stabilizers and corrosion inhibitors are used. Lewisite during storage must be protected from moisture because it is relatively easy to hydrolyze. The products of hydrolysis are hydrochloric acid and 2-chloroethenyl arsenic oxide, a poison and skin irritant.[0778]

Lewisite is shipped under DOT regulations for a Poison, Class A. It is accepted for shipment by freight but not express.[0778]

Lewisite and lewisite contaminated wastes should be handled only by an experienced decontamination team, equipped with impermeable protective clothing, and suitable gas masks. The protective clothing should constitute a total body shield. A supply of BAL should be kept in readiness for use. Optimum procedure, if time permits, is to use Department of Defense (Army, Navy or Air Force) decontamination teams, in preference to non-governmental, civilian personnel.

No lewisite should be released to the environment and the release of arsenite compounds formed upon the treatment of lewisite should be limited. The recommended maximum concentration of arsenic compounds as arsenic dicharged to streams is 1.0 ppm and the maximum recommended in drinking water is 0.05 mg/l.[0536] The recommended provisional limits for arsenic compounds for air and water are 0.005 mg/M^3 and 0.05 mg/l as As, respectively.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Option No. 1 - Chlorination

In dilute aqueous solution chlorine converts lewisite into arsenic trioxide and dichlororethene. Dichloroethene requires further treatment as a chlorinated organic compound.[0778] Arsenic trioxide is slightly soluble and hence should not be placed in a landfill as such. If arsenic trioxide is reacted with a suspension of magnesium hydroxide, insoluble magnesium arsenite is formed.[2345] The magnesium arsenite thus precipitated and the excess magnesium hydroxide can be stored under controlled conditions, or the slurry can be evaporated and stored in a permanent disposal area. Aqueous chlorine or sodium hypochlorite treatment, followed by reaction with magnesium hydroxide is satisfactory for decontamination or disposal of lewisite even though an arsenite is produced that must be in indefinite long term storage.

Option No. 2 - Hydrolysis

Both cis- and trans- isomers of lewisite are completely decomposed in sodium hydroxide solutions at temperatures above 40 C. The reaction proceeds as follows:

$$Cl\text{-}CH{=}\,CH\text{-}AsCl_2 \xrightarrow[H_2O]{NaOH} Na_3AsO_3 + 3NaCl + CH{=}CH\uparrow + H_2O\cdot^{0778}$$

The sodium arsenite produced is soluble and requires treatment with magnesium hydroxide, as noted above, to form insoluble magnesium arsenite before disposal in a controlled storage facility (lined lagoon, tank, abandoned quarries or mines, etc.).[2345]

Option No. 3 - Incineration (Transportable Disposal System)

The Transportable Disposal System which is described in the Profile Report on Organophosphorus Nerve Agents [287,288] can be applied to munitions or tanks containing lewisite in concentrated form. The combustion products are carbon dioxide, water, HCl and aresenic trioxide. The arsenic trioxide removed by alkaline scrubbing should be converted to the insoluble magnesium salt and placed in controlled storage.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The extreme hazards to man associated with lewisite require that surplus, scrap or obsolete lewisite and munitions containing lewisite be disposed of at National Disposal Sites operated by the U.S. Army. Options No. 1, 2 and 3 are recommended for disposal of lewisite in concentrated form, while only Option No. 3 is recommended for disposal of munitions containing lewisite.

7. REFERENCES

0536. Water quality criteria. Report of the National Technical Advisory Committee to the Secretary of the Interior. Washington, Federal Water Pollution Control Administration, Apr. 1, 1968. 234 p.

0778. Franke, S. Manual of military chemistry. Chemistry of Chemical Warfare Agents. v. 1. Washingtion. Office, Assistance Chief of Staff for Intelligence, Department of the Army, 1968. 375 p.

2345. Latimer, W. M., and J. H. Hildebrand. Reference book of inorganic chemistry. New York, the Macmillan Company, 1942. 552 p.

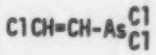
HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Lewisite

IUC Name 2-chloroethenyl dichloroarsine (trans and cis forms)

Common Names Lewisite; Dichloro - (2-Chlorovinyl) Arsine

Structural Formula



$\mathrm{ClCH{=}CH{-}As}\begin{smallmatrix}\mathrm{Cl}\\\mathrm{Cl}\end{smallmatrix}$

Molecular Wt. 207.32

Melting Pt. -2.4 C (trans)(1) -44.7 C (cis)

Boiling Pt. 196.6 C (trans)(1) 169.8 C (cis)

Density (Condensed) 1.86 g/cc @ 25 C

Density (gas) 7.15 @ 20 C

Vapor Pressure (recommended 55 C and 20 C)

0.4 torr @ 25 C (trans)(1)

1.562 @ 25 C (cis)(1)

@

Flash Point

Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.5 g/l

Hot Water

Ethanol

Others: soluble - gasoline, most organic solvents

Acid, Base Properties

Highly Reactive with Water, base, aqueous chlorine

Compatible with

Shipped in stainless steel

ICC Classification Poison, Class A

Coast Guard Classification Poison, Class A

Comments

References (1) 0778

PROFILE REPORT

Magnesium Arsenite (245)

1. GENERAL

The Profile Reports on Calcium Arsenite (88), Sodium Arsenite (377), Copper Acetoarsenite (490), Lead Arsenite (236), Potassium Arsenite (341), Zinc Arsenite (454), and Arsenic Trioxide (51) indicate that for waste arsenite compounds and arsenic trioxide, long term storage is the best option for waste management. Disposal of arsenite compounds or arsenic trioxide in typical landfills is not recommended because of their high toxicity and appreciable (though slight) solubility. Though the quantity of arsenite projected for manufacture over the next five years is small, considerable arsenic trioxide will be collected as a byproduct of copper, lead, and gold smelting industries and as a residue from destruction by combustion of organic compounds containing arsenic.[0634]

Even though the arsenite compounds and As_2O_3 are stored in sealed containers, their solubility creates a potential problem. Ferric and magnesium arsenites are very slightly soluble. Therefore, the arsenites and As_2O_3 can be rendered nearly insoluble by addition to a suspension of magnesium hydroxide, and thus their long term storage made safer.

The physical/chemical properties of mganesium arsenite are not given because magnesium arsenite is not a compound but a name applied to a group of compounds.

2. TOXICOLOGY

All arsenic compounds are highly toxic materials and are very dangerous even in low concentrations.[0766] However, the solubilities of mixtures of arsenites and magnesium hydroxide are so low that these mixtures are relatively non-toxic, magnesium hydroxide being given to treat arsenite or

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As_2O_3 poisoning. The American Conference of Governmental Hygienists recommended a Threshold Limit Value (TLV) of 0.5 mg per cubic meter for all arsenic compounds.[0225] A detailed discussion on arsenite toxicology is given in the Profile Report on the Arsenite Compounds (88, etc.).

3. OTHER HAZARDS

Magnesium arsenite does not exhibit any explosive, flammable, or volatile properties nor does it present any other hazards in an alkaline environment. When reacted with strong acids, the arsenic content of the material is solubilized.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

As previously indicated, magnesium arsenite is formed in the treatment of other arsenic wastes. It has no other known use. Magnesium arsenite with magnesium hydroxide should be handled in the same manner as described in the Profile Report on the Arsenites (88, etc.).

The arsenite compounds are classified by DOT as Class B Poisons.

Because the wholesale disposal of arsenite compounds into the air, water or soil is considered completely unacceptable, aqueous discharge of arsenic compounds has been limited to concentrations below 1 ppm. Storage of arsenic compounds including As_2O_3 and the arsenites is usually in large, waterproof and siftproof storage bins or silos. This approach is expensive, but usually satisfactory. If the storage period is anticipated to be very long or the stored material is subject to exposure through natural causes, As_2O_3 or arsenite compounds should be added to a suspension of magnesium hydroxide. This mixture should be stored under the controlled conditions noted above.

5. EVALUATION OF WASTE MANAGEMENT

Techniques

As previously indicated, magnesium arsenite is made as a product of a waste treatment process. It should be stored in weatherproof and siftproof storage bins or silos without additional treatment except the water present may be permitted to evaporate. This is a recommended mode of disposal.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

As recommended in the Profile Report on Arsenite Compounds (88, etc.), processes for treating arsenite wastes should not be included in National Disposal Site schemes, but the site should be prepared to accept all forms of arsenic containing materials that are transported to it. Magnesium arsenite should be placed in long term storage until recovered for some useful purpose.

7. REFERENCES

0225. American Conference of Governmental Hygienists. Threshold Limits for 1971. Occupational Hazards, Aug. 1971. p. 35-40.

0634. Sullivan, R. J. Air pollution aspects of arsenic and its compounds. Bethesda, Litton Systems Inc., Sept. 1969. 72 p.

0766. Sax, N. I. Dangerous properties of industrial materials. 2d ed. New York, Reinhold Publishing Corporation, 1957. 1,467 p.

PROFILE REPORT

Pentachlorophenol (322)

1. GENERAL

Pentachlorophenol is a broad-spectrum biotoxicant available commercially in the form of flakes and needle crystals. Because of its high toxicity, it is also available in a prilled form and oiled grade to greatly reduce dust associated with the flakes and needles.[1433] The pure material melts at 191 C and decomposes at 310 C.[0766]

Pentachlorophenol can be manufactured by the direct chlorination of phenol and polychlorophenols. One commercial process[1433] uses a mixture of phenol, o-chlorophenol,2,6-dichlorophenol, and 2,4,6-trichlorophenol as the starting materials. Chlorination is carried out in the absence of solvents and catalyst until tetrachlorination is achieved; at that point a Lewis acid catalyst such as $FeCl_2$, $AlCl_3$, $SbCl_3$, etc., is added to facilitate the incorporation of the fifth chlorine group. The progress of the reaction is monitored by determining the freezing point of the product. When the proper freezing point is achieved, the chlorination is stopped, and the material is flaked and packaged. Pentachlorophenol is also manufactured by the hydrolysis of hexachlorobenzene[1433] with 5 to 15 percent sodium hydroxide in methanol at 130 to 140 C. The hexachlorobenzene is easily prepared by the liquid-phase, iron-catalyzed chlorination of benzene.

The textile industry uses pentachlorophenol to preserve rope, binder twine, burlap, cable covering and rubberized canvas belting. It is also utilized by the wood and construction industries to impart termite resistance to wood and to control mold growth on lumber products and building surfaces. The pentachlorophenol is generally incorporated in the treating of materials such as whitewash or paints, or mixed with oil for spray application. It also finds use in the leather industry to impart temporary mold resistance to upper leather for shoes,[1512] and as a fungicide and herbicide.[1277]

Domestic production of pentachlorophenol was reported as 47.2 million pounds while the quantity sold was 45.8 million pounds for the year 1970, the remainder being for captive use. Manufacturers of pentachlorophenol are Dow Chemical Co., Monsanto Co., Reihhold Chemicals Inc., Sanford Chemical Co., and Vulcan Materials Co.[1718]

2. TOXICOLOGY[1512]

Pentachlorophenol is capable of producing severe irritation and corneal damage upon contact with the eye. A single short exposure to the skin may cause some reddening, while repeated or prolonged contact may cause severe irritation or burns. This material is readily absorbed through the skin in toxic amounts, particularly from solutions, and is highly toxic if swallowed. Dust concentrations which are hazardous are very irritating to the nose and throat. The material is not likely to cause sensitization nor should there be any problem from ingestion incidental to correct industrial handling.

The Threshold Limit Value (TLV) and maximum allowable concentration[0766] is 0.5 mg/M^3. LD_{50} for rats is 125-210 mg/Kg orally and 150-350 mg/Kg dermal.[1277]

3. OTHER HAZARDS

Although pentachlorophenol has no fire or flash point, it is dangerous when heated to decomposition. Decomposition takes place at 310 C with the emission of highly toxic fumes of chlorides.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, Transportation[1512]

Safety glasses with side shields, or their equivalent, should be worn when this material or its solutions are handled. Where the likelihood of appreciable exposure to dust or strong solutions cannot be avoided, workers should wear appropriate protective devices, including underwear with full length arms and legs, coveralls, or other outer garments covering the whole body, cloth gloves, cap, and a dust respirator bearing the approval of the U. S. Bureau of Mines for use with toxic dusts. Impervious sleeves with elastic bands at either end, to fit over long gauntlet gloves, may be useful for protecting the arms and wrists. For extensive manual operations it may be necessary to utilize protective rubber gloves.

Disposal/Reuse

A definition of acceptable criteria for the disposal of pentachlorophenol must also take into account acceptable criteria for the release of hydrogen chloride and hydrochloric acid to the environment, since current practice in pentachlorophenol disposal involves some processes that reduce pentachlorophenol to these materials.

Current disposal techniques utilize incineration and land burial. These methods are acceptable provided the concentration of pentachlorophenol, hydrogen chloride and hydrochloric acid in effluent streams released to the environment do not exceed the following recommended maximum concentrations:

Contaminant and Environment	Maximum Concentration for Continuous Exposure	Basis of Recommendation
Pentachlorophenol released to the atmosphere	0.005 mg/M^3 /24 hr.	0.01 TLV
Hydrogen chloride released to the atmosphere	0.05 ppm (0.07 mg/M^3)/24 hr.	0.01 TLV
Hydrochloric acid released to the atmosphere	0.05 ppm (0.07 mg/M^3)/24 hr.	0.01 TLV

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Little information is available from literature and industrial sources pertaining to the disposal of pentachlorophenol waste streams. However, pentachlorophenol is chemically and structurally similar to other chlorophenoxy compounds such as 2,4-D (2,4-dichlorophenoxy acetic acid), 2,4,5-T (2,4,5-trichlorophenoxy acetic acid), and MCPA (2-methyl-4-chlorophenoxy acetic acid), and it is therefore assumed that processes applicable to those wastes are applicable to pentachlorophenol wastes. The various processes for treating concentrated and dilute chlorophenoxy waste streams are discussed in detail in the Profile Report covering 2,4-D (135). The salient points of those discussions are presented in the following sections of this report.

Dilute Pentachlorophenol Wastes

Option No. 1 - Adsorption with Powdered Activated Carbon. The addition of powdered activated carbon to dilute aqueous waste streams followed by stirring and filtration has proven to be an adequate method of low concentration chlorophenoxy compound removal. Studies have shown that compounds such as 2,4-D and probably pentachlorophenol can be removed with as high as 99 percent efficiency under certain processing conditions (carbon dosage of 320 mg/liter, a pH of 6, and one hour contact time as in the case of a 10 ppm 2,4-D waste stream). The carbon adsorbent may then be collected for disposal or the pentachlorophenol may be removed in rotary hearth incinerators equipped with hydrogen chloride scrubbers. The activated carbon may then be recycled.

Option No. 2 - Adsorption with Granular Activated-Carbon Beds. This method of treatment has been successfully utilized to treat wastewater containing 2,4-D and 2,4,5-T with removal efficiencies as high as 99 percent. The concentrated chlorophenoxy compounds are removed from the carbon adsorbent through controlled oxidation in rotary hearth incinerators with subsequent effluent scrubbing to remove chlorides. Because the technology is proven and since it is a well established chemical engineering unit operation, adsorption with granular activated-carbon beds should be considered as one of the more satisfactory methods for treating dilute pentachlorophenol wastes.

Option No. 3 - Biological Degradation. Biological degradation of dilute waste streams containing dichlorophenol has been utilized. One such process started with pretreatment of the waste stream by first sending it through a crushed limestone filled neutralization ditch and an in-plant equalization pond, and a final pH adjustment to 7.2 by automatic addition of slaked lime slurry in a continuous stirred pit. The wastewater, containing 2 to 4.2 mg/liter phenoxy acids, was then treated in an aerated lagoon and stabilization pond system before discharge to a receiving stream. Although the removal of chlorophenoxy acids by the lagoon and pond system ranged from only 49 to 80 percent, the stabilization pond effluent with typically 1.1 mg/liter chlorophenoxy acids was considered to be good quality. This would indicate that streams containing pentachlorophenol (instead of dichlorophenol) could possibly be biologically treated, however more work needs to be done in this area to establish proper processing parameters.

Option No. 4 - Ion Exchange. The use of ion exchange columns to remove chlorophenoxy compounds such as the sodium salt of 2,4-D from water has been examined. It was determined that when chlorophenoxy compounds are neutralized to their sodium salts, that ion exchange can remove concentrations as high as 120 mg/liter completely using strongly basic anion resins. It would appear that ion exchange is an adequate method for treating dilute pentachlorophenol wastes.

Concentrated Pentachlorophenol Wastes

Option No. 1 - Incineration. The complete and controlled high temperature oxidation coupled with adequate scrubbing and ash disposal facilities offers the greatest immediate potential for the safe disposal of concentrated pentachlorophenol. The research on incineration of pesticides conducted by Kennedy et al at Mississippi State University has led to the conclusion that chlorophenols approach complete oxidation when combusted at temperatures in the 600 C to 900 C range with hydrogen chloride being the only pollutant liberated. If proper scrubbing systems are utilized, efficient abatement of the hydrogen chloride can be achieved. Therefore, properly designed and operated incineration is considered the best present and near future method for the disposal of concentrated pentachlorophenol.

Option No. 2 - Deep-Well. Although pentachlorophenol is only sparingly soluble in water, its persistence and stability in water and the potential contamination of ground water make deep-well at best a questionable method for disposal. The method is not recommended by the National Working Group on Pesticides, and should be considered only under very special situations where hazards would be nonexistent.

The disposal of pentachlorophenol wastes as well as other chlorophenoxy wastes in open pits, lagoons, unapproved landfill sites, by application to the soil surface, and by on site burning or deep sea burial are not recommended practices because of the obvious potential contributions to air and water pollution.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

It is anticipated that disposal systems to handle both dilute and concentrated pentachlorophenol and similar compounds will be required at National Disposal Sites located near manufacturers, users, and especially agriculture centers in the near future. The dilute pentachlorophenol wastes that will require treatment include spent cleaning solutions for pentachlorophenol containers and any other contaminated wastewater. The concentrated pentachlorophenol wastes that will require treatment include any surplus, contaminated or fully degraded material.

The processes recommended for the treatment of dilute pentachlorophenol wastes at National Disposal Sites are:

Process	Order of Preference	Remarks
Activated-Carbon Beds	First Choice	Proven technology on commercial scale; also adequate for removal of the sodium salt of pentachlorophenol and most other types of pesticides from wastewater.
Ion Exchange	Second Choice	Demonstrated technology; requires preliminary conversion to the sodium salt.
Biological	Third Choice	Demonstrated technology on closely related compounds; requires treatment in aerated lagoons and stabilization ponds.

The processes for the treatment of concentrated pentachlorophenol wastes at National Disposal Sites are:

Process	Order of Preference	Remarks
Incineration	First Choice	Demonstrated technology; applicable to the disposal of most organic wastes; possibility of recovering chlorine in the form of usable hydrogen chloride.

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Pentachlorophenol

IUC Name Pentachlorophenol[2]

Common Names Pentachlorophenol, Penta Santophen 20, Dowicide 7

Structural Formula

C_6Cl_5OH[1]

Molecular Wt. 266.35 (1)   Melting Pt. 190 C (1)   Boiling Pt. 310 C (decp) (1)

Density (Condensed) 1.978 @ 22/4 C[2]   Density (gas) ____ @ ____

Vapor Pressure (recommended 55°C and 20°C)

5.5 @ 160 C (3)   50 @ 220 C (3)   550 @ 300 C (3)

Flash Point None (3)   Autoignition Temp. ____   Fire point - none (3)

Flammability Limits in Air (wt %)   Lower ____   Upper ____

Explosive Limits in Air (wt. %)   Lower ____   Upper ____

Solubility

Cold Water Almost insoluble (1)   Hot Water ____   Ethanol Freely soluble (1)

Others: Freely soluble in ether (1), soluble in benzene (1)

Acid, Base Properties Acidic, pK_a = 4.86 (1)

Highly Reactive with ____

Compatible with ____

Shipped in Multiwall paper bags (3), fiber drums (3)

ICC Classification ____   Coast Guard Classification ____

Comments LD_{50} orally in rats: 180 mg/Kg (1)   MAC: ACGIH; 0.5 mg/M (3) of air

References (1) 1492   (4) 1433
(2) 1570
(3) 1512

7. REFERENCES

0766. Sax, N. Irvine. Dangerous properties of industrial materials. Reinhold Publishing Corporation, New York, 1957. 1,467 p.

1277. Bailey, J. B. and J. E. Swift. Pesticide information and safety manual. Berkeley, University of California, Division of Agricultural Science, 1968. 147 p.

1433. Kirk-Othmer encyclopedia of chemical technology. 2d ed. New York, Interscience Publishers, 1963.

1492. Merck and Company. The Merck index of chemicals and drugs. Rahway, New Jersey, 1960. 1,043 p.

1512. Dow Chemical Company. Antimicrobial agents. Technical Bulletin I-6. Midland 1969. 5 p.

1570. The Chemical Rubber Company. Handbook of chemistry and physics. 47th ed., Cleveland, 1962. 2,100 p.

1718. U. S. Tariff Commission. Synthetic organic chemicals; United States production and sales, 1970. T. C. Publication 479. Washington D. C., U. S. Government Printing Office. 1971. 262 p.

PROFILE REPORT

Perchloric Acid (To 72 Percent Strength) (324)

1. GENERAL

In its usual commercial form, 70 to 72 percent aqueous solutions, perchloric acid has no oxidizing power in the cold. Its properties are those of a strong acid. The cold 72 percent acid reacts with active metals with the liberation of hydrogen and formation of perchlorates. When heated, reduction of the perchlorate ion begins to take place and hydrogen chloride becomes a product. The lack of oxidizing power of cold perchloric acid permits the preparation of numerous organic salts of the acid thus establishing its wide use in the titration of organic bases in non-aqueous solvents. The hot, concentrated acid, however, is a strong oxidizing agent which makes it useful in analytical work for wet ashing organic matter and in the determination of chromium in steel.

Most commercial perchloric acid is made by the Pernet Process in which sodium perchlorate is dissolved in water and reacted with an excess of concentrated hydrochloric acid to precipitate sodium chloride. The sodium chloride is filtered off to give a filtrate containing about 32 percent perchloric acid. The hydrogen chloride is boiled off, condensed and returned to react with additional sodium perchlorate. The dilute perchloric acid is then concentrated by evaporation to about 57 percent while any remaining hydrogen chloride is lost in the vapors which should be scrubbed. The crude perchloric acid is vacuum distilled in a glass or glass-lined still to produce a product of 70 to 71 percent perchloric acid. Sodium perchlorate crystals form as a waste product, but these are recovered and added to the sodium perchlorate used in the initial reaction.[1156]

The physical/chemical properties for perchloric acid are summarized in the attached worksheet.

2. TOXICOLOGY

Perchloric acid is considered only slightly toxic. However like other strong acids, perchloric acid in the form of liquid, mist or vapor is highly corrosive to the skin, eyes and mucous membranes. The amount of damage will depend upon the concentration, temperature, and duration of contact. Perchloric acid is considered to be a primary skin irritant. Since perchloric acid is not very volatile, the types of injury most likely to occur in industry are irritation of the respiratory tract through inhalation of the mist or spray, and severe burns of the eyes and skin through contact with the liquid.[0766, 1156]

When diluted and neutralized with sodium, potassium, or calcium hydroxides or carbonates, the perchlorate ion is slightly toxic. Oral doses of 200 to 400 mg of potassium perchlorate every eight hours for periods up to 52 weeks were given to treat hyperthyroidism in humans. Other than a decrease in the serum concentration of protein-bound iodine, no significant changes in the subjects were noted.[1156]

Goldfish in water containing 0.1 percent sodium perchlorate were not affected; but when the sodium perchlorate concentration was raised to 0.2 percent, one in five fish died after 24 hours exposure.[1156]

3. OTHER HAZARDS

Anhydrous perchloric acid undergoes spontaneous explosive decomposition in storage, and will explode as the result of violent reaction with traces of contaminants. For this reason anhydrous $HClO_4$ should not be prepared except for research purposes in small quantities, and anything which will dehydrate 72 percent $HClO_4$ should be avoided. Dehydration takes place upon vacuum distillation, and (explosively) on contact with concentrated H_2SO_4. Perchloric acid in excess of 72 percent concentration is prohibited from shipment and in some areas a special permit is required to prepare anhydrous perchloric acid. Even the aqueous solution of 72 percent perchloric acid requires special precautions in its use. Contact of perchloric acid solution with easily oxidized or combustible materials or with dehydrating or reducing agents may result in fire or explosion. If used in wet combustion of organic material, the sample must first be treated with nitric acid to destroy easily oxidized organic matter.[0766, 1156]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Cold 72 percent perchloric acid reacts with active metals with the liberation of hydrogen and formation of the perchlorates. Marked passivity is noted in certain cases, e.g., iron, chromium and nickel. Only the platinum metals and glass are not attacked by hot perchloric acid which limits the construction of equipment used in handling perchloric acid.

Perchloric acid, providing the concentration does not exceed 72 percent by weight, is classified by DOT for shipment as a corrosive liquid under a "White Acid Label". Perchloric acid solutions, in inside bottles having a capacity not over 1 lb or 16 oz by volume, enclosed in a metal can, are exempt from special packaging, marking and labeling requirements. Each box with larger inside containers and carboys must bear a White Acid Label.[1156]

Waste streams containing perchloric acid must be neutralized to a pH of 6.5 to 9.2 before discharging into streams or lakes.[0536] The concentration of perchlorate ion discharged should not exceed 0.1g/100g of water; 0.2g/100g of water is the concentration above which goldfish can not survive.

5. EVALUATION OF CURRENT AND NEAR FUTURE PERCHLORIC ACID DISPOSAL PROCESSES

The recommended disposal procedure by the Manufacturing Chemists Association for packaged lots of perchloric acid is to add the acid to a large volume of a reducer such as sodium thiosulfate, a bisulfite or a ferrous salt acidified with $3M\text{-}H_2SO_4$.[0095] The reported reduction does not take place in the cold but heating is required to reduce the perchlorate ion. The reduction of perchloric ion to chloride with heated ferrous sulfate is recommended for use with extreme care. The reduction products must be tested to determine that complete reduction of the perchlorate ion has occurred.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

It is not anticipated that large quantities of aqueous perchloric acid solutions (up to 72 percent in concentration) will require disposal. However, because of the hazards associated with the destruction of perchloric acid, treatment of excess or waste perchloric acid at National Disposal Sites is recommended. The process recommended is the hot reduction with ferrous sulfate and dilute sulfuric acid.

7. REFERENCES

0095. Manufacturing Chemists Association. Laboratory waste disposal manual. 3d ed. Washington, Manufacturing Chemists Association, 1970. 176 p.

0536. Water quality criteria. Report of the National Technical Committee to the Secretary of the Interior. Washington, Federal Water Pollution Control Administration. Apr. 1, 1968. 234 p.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 1,251 p.

1156. Schumacher, J. C. Perchlorates, their properties, manufacture and uses. New York, Reinhold Publishing Corporation, 1960. 257 p.

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Perchloric acid

IUC Name Perchloric acid

Common Names

Structural Formula

$HClO_4$

Molecular Wt. 100.47(1) Melting Pt. -112 C(1) Boiling Pt. 16 C(8 torr)(1)

Density (Condensed) 1.764 @ 20 C(1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water soluble(1) Hot Water soluble(1) Ethanol soluble(1)

Others: acetic acid, most polar organic solvents - soluble(1)

Acid, Base Properties strong acid(1)

Highly Reactive with Reducing substances and active metals(1)

Compatible with

Shipped in Glass bottles 1 and 5-lb, carboys 2,5 and 10-gal(1)

ICC Classification corrosive liquic, white label(1) Coast Guard Classification Corrosive liquid, White Label (1)

Comments Forms constant boiling mixture containing 71.6 percent acid.

References (1) 1156

PROFILE REPORT

Phosphorus, White or Yellow (332)

1. GENERAL

Introduction

Elemental phosphorus has four allotropic forms, all tetra-atomic at room temperature. This Profile Report covers only the white allotrope, which is the most hazardous common form of the four, because it is highly poisonous and extremely inflammable.

White phosphorus turns yellow upon heating. It is a wax-like substance, of low melting point, very low heat of fusion, and high volatility. White phosphorus smolders and ignites spontaneously in dry air, and is usually kept under water from which all of the oxygen has been expelled by boiling. The material glows in the dark, with a yellow light.

White phosphorus is manufactured by condensing the phosphorus vapor obtained by electrothermal (electric furnace) reduction of phosphate rock with coke. The raw materials for the process are phosphate rock, coke, and silica. In 1968, over 650,000 tons of phosphorus were produced in electric furnaces in the United States[1668] by the following reaction:

$$3Ca_3(PO_4)_2 \cdot CaF_2 + 9SiO_2 + 15\ C \xrightarrow{1500C} 1\text{-}1/2\ P_4\uparrow + 9(CaO \cdot SiO_2) + 15CO\uparrow$$

The phosphorus produced is employed almost completely as an intermediate product. The largest single use is the manufacture of furnace H_3PO_4. The condensed elemental phosphorus is burned in air to produce phosphorus oxide vapor, which is reacted with water to yield phosphoric acid.

Physical and Chemical Properties

The physical and chemical properties of white phosphorus are summarized on the attached worksheet.

2. TOXICOLOGY

Elemental white or yellow phosphorus and phosphine (PH_3) are the only inorganic phosphorus compounds with recognized systemic toxicity. Skin contact with white phosphorus produces painful, slow-healing, second and third degree burns, due to both chemical and thermal damage. White phosphorus is a general protoplasmic poison when introduced via either inhalation or ingestion. Its toxicity is enhanced when the material is dissolved in solvents such as alcohol, fats or oils, or when the material is finely divided.

The acute fatal dose of white P_4 for an adult is between 50 and 100 mg, although recovery has occurred after 1.5 gm.[2376] Fatality rates are about 50 percent. Acute poisoning occurs typically in three stages. The first stage produces symptoms due to local irritation. The effects are not immediate, except for thermal burns due to contact with the body surface. Nausea, vomiting, diarrhea, and severe abdominal pain occur. If the quantity inhaled or ingested is very large, shock is severe and death may occur from cardiac collapse in the first 24 to 48 hours.[2028] The second stage is frequently symptom free, and may last from 8 hours to several weeks, with apparent recovery during this period. The third stage, involving symptoms of systemic toxicity due to the action of elemental phosphorus as a general protoplasmic poison, is normally terminated by death in 4 to 8 days, but may last as long as three weeks before death occurs. Symptoms include nausea, vomiting, diarrhea, massive hematemesis, hemorrhages into the skin, mucous membranes and viscera, liver damage including hepatic failure, cardiovascular collapse, and central nervous system involvement. If the victim survives, cerebral symptoms may continue for a protracted period.[2028]

Chronic poisoning, due to ingestion or inhalation of sub-lethal dosages produces cachexia, anemia, bronchitis, general debility and necrosis of the mandible-known as "phossy jaw".[2376]

The Threshold Limit Value (TLV) for white phosphorus is 0.1 mg per cubic meter. The provisional limits recommended for air and water are 0.001 mg per cubic meter and 0.005 mg per liter respectively.

3. OTHER HAZARDS

Phosphorus is not explosive nor is the smoke generated from its combustion. It does ignite spontaneously upon contact with air or oxygen and gives off great clouds of white smoke during combustion. Phosphorus melts at 44.1 C and when thoroughly melted, it becomes a liquid which flows and spreads even more readily than light penetrating oils or gasoline. In this form it combines readily with oxygen and burns rapidly in air. Fires can be controlled by covering with water, sand or earth to exclude air.[1881]

The P_4O_{10} fumes produced by burning phosphorus are extremely irritating, and react with any source of water to form corrosive phosphoric acid. If combustion occurs within a confined space, asphyxiation may occur due to consumption of oxygen by the burning phosphorus.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

In the manufacture of phosphorus by the electric furnace method "phossy water" containing suspended phosphorus and ferrophosphorus ore formed as waste and by-products. In handling phosphorus under water, small bits of phosphorus break off the edges of phosphorus lumps and "phossy water" is formed. The other waste stream from phosphorus production is the ferrophosphorus obtained as a by-product due to the iron content of the phosphate ores. The phosphorus content of ferrophosphorus is about 23 to 25 percent.

Phosphorus, white or yellow, is classified by DOT as an inflammable solid with a yellow label. It is shipped either under water or dry, by rail, water or highway. Dry phosphorus may not be shipped by rail-express, but dry shipment is rarely, if ever, used.[1881]

The Manufacturing Chemists' Association in Chemical Safety Data Sheet SD-16 summarizes the information required for white phosphorus plant design, handling, storage and shipping.[1881] Personnel handling phosphorus wastes should wear the prescribed protective clothing.

Many rat poisons and other vermin poisons contain as much as 1 to 4 percent white phosphorus, combined with such diluents as oil, flour, sugar, and coloring matter.[2028] These economic poisons remain a major source of phosphorus poisoning in humans.

Phosphorus should not be released to the environment at levels higher than those noted below. Abatement processes should convert recovered phosphorus to phosphoric acid. The recommended maximum concentrations of phosphorus or phosphoric acid in effluent streams are as follows:

Contaminant and Environment	Provisional Limit	Basis for Recommendation
Phosphorus released to the atmosphere inside or outside the boundaries of the processing plant	0.01 $mg/M^3/24$ hr	0.1 TLV[0225]
Phosphoric acid mist released to the atmosphere inside or outside the boundaries of the processing plant	0.01 $mg/M^3/24$ hr	0.1 TLV[0225]
Phosphoric acid after adjustment to pH 6.5 to 9.0, released to streams or sewers	50 mg/ℓ	Level where overgrowth of objectional plant forms begin

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

The current disposal technique most frequently employed for "phossy water" is to lagoon the material in a pond within the boundaries of the electrothermal phosphorus plant. The phosphorus particles settle to the bottom of the basin, and are slowly oxidized by the oxygen dissolved in the water to hypophosphorous, phosphorous and phosphoric acids, which enter the water table. This method of disposal is not acceptable.

Ferrophosphorus is generally used as an alloying constituent in the manufacture of certain steels. The material is also subjected to destructive distillation at 1400 to 1500 C, and the phosphorus vapors produced are condensed under water.[0955, 1662] The white phosphorus thus produced is used for the same purposes as normal electric furnace phosphorus. Both of these techniques are acceptable processes for disposal via recycle and reuse.

The options listed below are those recommended for the disposal of phossy water, rat and other vermin poisons based on white phosphorus, and contaminated bulk white phosphorus.

Option No. 1 - Oxidation of Suspended Particles in Water, "Phossy Water"

Phosphorus in "phossy water" is oxidized by spraying into an incinerator equipped with an alkaline scrubber or it is oxidized by blowing through a flame followed by an alkaline scrubber.[1881]

Option No. 2 - Open Burning

Rat and vermin poisons and other solid or pasty residues containing phosphorus should be burned in an isolated location, the residue neutralized and diluted with water to a phosphate concentration less than 50 mg per liter.[0095]

Option No. 3 - Conversion to Phosphoric Acid

Contaminated phosphorus should be purified by distillation in an inert gas stream at temperatures over 280 C. The phosphorus vapor produced should be condensed under water, and recycled for sale to the furnace phosphoric acid industry. Alternatively, the contaminated phosphorus can be charged to the electric furnace used for phosphorus production.

Option No. 4 - Controlled Incineration-Municipal Incinerators

Rat and vermin poisons which contain white phosphorus and other small lots of wet phosphorus wastes, if properly segregated to permit safe handling, can be burned in municipal incinerators equipped with automatic conveying equipment and scrubbing and mist removal devices. The fly ash produced in such incinerators will generally neutralize the H_3PO_4 made.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

It is anticipated that small quantities of white phosphorus contaminated wastes can be treated adequately by municipal incinerators as per Option No. 4 if transported sealed or under water. If large quantities of phosphorus wastes must be treated, the wastes should be shipped in air tight containers to the nearest manufacturing plant capable of recovering phosphorus via Option No. 3. It is, therefore, not recommended that provision be made at National Disposal Sites for the disposal of phosphorus.

7. REFERENCES

0095. Manufacturing Chemists Association. Laboratory waste disposal manual. 2d ed. Washington, 1969. 176 p.

0225. American Conference of Government Industrial Hygienists. Threshold limit values for 1971. Occupational Hazards, p. 35-40. Aug., 1971.

0536. Water quality criteria. Report of the National Technical Advisory Committee to the Secretary of the Interior. Washington, Federal Water Pollution Control Administration, Apr. 1, 1968. 234 p.

0955. Sittig, M. Inorganic chemical and metallurgical process encyclopedia. Park Ridge, New Jersey, Noyes Development Corporation, 1968. 833 p.

1416. Ross, A., and E. Ross. The condensed chemical dictionary. 6th ed. Ross and Ross, 1961.

1662. Shreve, R. N. Chemical process industries. 2d ed. New York, McGraw-Hill Book Company, 1956. 1,004 p.

1668. Robinson, J. M., G. I. Gruber, W. D. Lusk and M. J. Santy. Engineering and cost effectiveness study of fluoride emissions control. v. 1. TRW Systems Group, Jan. 1972. 560 p.

1881. Manufacturing Chemists' Association. Properties and essential information for safe handling and use of phosphorus, elemental. Washington, D. C., Safety Data Sheet SD-16, 1947. 13 p.

2028. Gonzales, T. A., M. Vance, M. Helpern, and C. J. Umberger. Legal medicine pathology and toxicology. 2d ed. New York, Appleton-Aubury-Crofts Inc. 1,349 p.

2376. Gleason, M. N., R. E. Gosselin, H. C. Hodge, and R. P. Smith. Clinical toxicology of commercial products. 3d ed. Baltimore, The Williams & Wilkins Company, 1969.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Phosphorus, white or yellow

IUC Name phosphorus, white

Common Names

Structural Formula

P_4

Molecular Wt. 124.08 Melting Pt. 44.1 C(1) Boiling Pt. 280 C(1)

Density (Condensed) 1.82g/cc @ 20 C(1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp. 30 C(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water insoluble(1) Hot Water Ethanol insoluble(1)

Others: soluble - carbon disulfide(1)

Acid, Base Properties

Highly Reactive with oxidizing substances, air(1)

Compatible with

Shipped in sealed containers under water(1)

ICC Classification Flammable solid(1) Coast Guard Classification Flammable solid(1)

Comments

References (1) 1416

PROFILE REPORT

Potassium Permanganate (349)

1. GENERAL

Potassium permanganate forms glittering dark purple crystals with a sweetish astringent taste. It is a strong oxidizing agent that decomposes at 240 C with the liberation of oxygen.

Potassium permanganate is prepared in two stages. In the first stage manganese dioxide (tetravalent Mn), is oxidized to manganate (hexavalent Mn) by passing an ore containing manganese dioxide mixed with a 50 percent solution of potassium hydroxide and steam through a series of rotary kilns. In the second stage of the process, the potassium manganate is dissolved in water, filtered and oxidized to potassium permanganate, either in an electrolytic cell or in a chemical process, In the chemical oxidation process, the filtered solution of potassium manganate is neutralized with carbon dioxide and heated; two-thirds of the potassium manganate is oxidized to potassium permanganate and one-third is reduced to manganese dioxide.[1433]

The uses of potassium permanganate depend on its oxidizing power. Important quantities are used for production of saccharin and benzoic acid since potassium permanganate oxidizes the methyl group of toluene and toluene derivatives to a carboxylic acid group. Manganese dioxide is obtained as a by-product. Potassium permanganate is also used for bleaching and decolorizing such materials as oils, fats, waxes and natural sponge. It is also used in textile bleaching, as a disinfectant and antiseptic for staining wood, and for forming tightly adherent oxide coatings on aluminum.[1433] Recently it has found considerable use in treating wastes such as phenols, aldehydes, ketones, esters, olefins, mercaptans, amines, tannins, lignins, hydrogen sulfide and lower oxides of nitrogen.[2300]

The physical/chemical properties of potassium permanganate are summarized on the attached worksheet.

2. TOXICOLOGY

Potassium permanganate solutions and dust are strong irritants to the eyes, nose and throat, and ingestion must be avoided during ordinary handling and storage operations. Prolonged ingestion of manganese compounds can produce chronic manganese poisoning, but the irritant effects from potassium permanganate would be so pronounced as to require treatment prior to the onset of any chronic toxic effects.[0766]

Drinking water standards limit $KMnO_4$ concentration to 0.05 mg/1, and critical concentration for fish toxicity is 3 mg/1.

3. OTHER HAZARDS

Potassium permanganate is a powerful oxidizing agent that is spontaneously flammable on contact with glycerin, ethylene glycol, and numerous other organic materials. It may detonate when severely shocked or exposed to high temperature.[2300] Storage of potassium permanganate in a cool, dry, fireproof building is recommended. Dry concrete floors are preferred to wooden floors. The material should be stored away from acids, organic solvents, oils and combustible materials.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Direct contact of potassium permanganate with reducing agents and organic materials should be avoided. Dry potassium permanganate is not corrosive to most metals. It may etch glass because it contains traces of potassium hydroxide. In neutral solutions, it is not corrosive to iron, aluminum, lead, zinc and alloys containing these metals. It attacks rubber and most fibers.

Potassium permanganate is shipped under DOT regulations for an oxidizing material. Small quantities are packaged in bottles or jars, with larger quantities shipped in steel drums containing 85 to 600 lb. The bulk material may also be shipped in hopper cars and trucks.[2300]

The amount of manganese in any form that is discharged in waste streams that enter storm sewers, streams or lakes should not exceed the recommended maximum of 1.0 ppm.[0536] Because manganese dioxide, the reduction product of potassium permanganate, is insoluble, the manganese in potassium permanganate waste streams may be a mixture of soluble potassium permanganate and manganese dioxide sludge.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Potassium permanganate is a valuable material that is often used to treat waste streams containing oxidizable substances. It is not anticipated that large quantities of potassium permanganate will ever require treatment as a waste. When disposal of waste or contaminated potassium permanganate is required, reducing substances such as phenolic wastes, sugar solutions or formaldehyde wastes can be added to a dilute solution of the potassium permanganate waste, maintaining a pH of 9 to 10. The potassium permanganate is reduced to the insoluble, colloidal hydrous manganese dioxide which should be removed by flocculation and lagooning, and placed in an appropriate landfill.[2300]

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Since most potassium permanganate wastes are likely to be discharged as relatively dilute solutions, the material is not considered economically feasible for National Disposal Site processing, and is not recommended as a candidate for National Disposal Sites. The simple method outlined in Section 5 for the reduction of potassium permanganate to insoluble manganese dioxide can be performed by any firm that handles potassium permanganate wastes.

7. REFERENCES

0536. Federal Water Pollution Control Administration. Water quality criteria, Washington, 1968. 234 p.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corp., 1968. 1,251 p.

1433. Kirk-Othmer encyclopedia of chemical technology. 2d ed. 22 v. and supplement. New York, Wiley-Interscience Publishers. 1963.

2300. Personal communication, R. A. Brenner, Carus Chemical Company, to R. S. Ottinger, TRW Systems, August 28, 1972

**HAZARDOUS WASTES PROPERTIES
WORKSHEET**

H. M. Name Potassium Permanganate

IUC Name Potassium Permanganate

Common Names ____

Structural Formula

$KMnO_4$

Molecular Wt. 158.03(1)   Melting Pt. 240 C decomposes(1)   Boiling Pt. ____

Density (Condensed) 2.7 g/cc @ 23 C(1)   Density (gas) ____ @ ____° ____

Vapor Pressure (recommended 55 C and 20 C)

____ @ ____°   ____ @ ____°   ____ @ ____°

Flash Point ____°   Autoignition Temp. ____°

Flammability Limits in Air (wt %)   Lower ____   Upper ____

Explosive Limits in Air (wt. %)   Lower ____   Upper ____

Solubility

Cold Water 6.3 g/100 g at 20 C(1)   Hot Water ____   Ethanol reacts(1)

Others: reacts with most organic solvents(1)

Acid, Base Properties ____

Highly Reactive with reducing substances(1)

Compatible with ____

Shipped in Hopper cars or steel drums(1)

ICC Classification oxidizing material, yellow label(1)   Coast Guard Classification oxidizing material, yellow label(1)

Comments ____

References (1) 1433

PROFILE REPORT

ZINC COMPOUNDS

Zinc Chloride (456), Zinc Cyanide (457), Zinc Nitrate (459), Zinc Permanganate (461), Zinc Peroxide (462), Zinc Sulfide (463)

1. GENERAL

The zinc compounds, as a class, have been identified as Category II compounds. With specific exceptions they do not have serious toxicities and can be adequately handled by current industrial or commercial treatment methods. These compounds will be discussed as a class in this profile and important exceptions to general remarks will be cited.

Zinc chloride is the second most commercially important zinc compound after zinc oxide. Most, if not all, of the zinc chloride produced in the United States is derived from secondary zinc sources such as zinc dross and sal skimmings. They are normally treated with muriatic acid and the product solution is filtered off. The nearly dry residue is then chlorinated. The resulting, additional zinc chloride is leached with water and added to the original filtrate. Concentration and purification follows. Zinc chloride is used in combination with other compounds as a wood preservative and fire proofing lumber. It is used as a deodorant, in disinfectants, embalming fluids, as a fungicide, in the manufacture of vulcanized fiber and parchment paper, as a dyeing mordant, in oil refineries, galvanizing and manufacture of dry batteries.[2377] Zinc is the largest plating commodity and zinc chloride is widely used in the industry. Production of $ZnCl_2$ in the United States was 28,000 tons in 1966.

Zinc cyanide is also used extensively in the metal plating and finishing industry. Its volume is much greater than zinc chloride although the acid-chloride baths are being rapidly developed. The types of plating techniques for zinc normally result in larger amounts of zinc wastes per unit plated than for the other common plating metals.[2350] Plating waste treatment can generally be characterized as needing improvement. An estimated 50 percent of cyanide users are still discharging to sewers under control and permit of authorities. Almost all plants are also required to have destructive precipitation and clarification facilities but the clarifiers do not operate very efficiently and often allow some of the precipitated wastes to escape to the sewer.

Zinc sulfide is used as a pigment in paints and plastics. It exhibits phosphorescence when very pure and is used in cathode ray tubes, TV picture tubes and luminous watch dials. It is insoluble in water and does not constitute a hazard unless exposed to acids.

Zinc nitrate is believed to be made by reacting a zinc source with nitric acid. The pattern of purchase by industries indicate that it is used in textile dyeing and engraving.[2360] Its consumption for all purposes was not available.

Zinc permanganate is classed as a rarely used compound by its sole commercial manufacturer. Its use is believed to be confined to pharmaceuticals as an oxidizing agent where it is much more soluble than the commonly used potassium permanganate. Sales are certainly less than 1,000 lb annually and probably less than 50 lb.[2361]

Zinc peroxide is used in pharmaceuticals and as a curing agent for polysulfides. It is consumed in the reactions where it is added and is not believed to occur anywhere as a specific waste. It slowly decomposes to zinc oxide. In polymer formulation the zinc residues are of course bound up and present no significant hazard.

Physical Properties

The available physical and chemical properties of the materials discussed in this Profile Report are included in the attached worksheets.

2. TOXICITY

Zinc compounds in general, with the exception of zinc cyanide, are not inherently very toxic. The hazard of zinc cyanide is mainly attributed to the cyanide constituent. The general toxic effects of the zinc compounds are noted in three distinct areas of exposure: inhalation, ingestion and skin contact.

Inhaled zinc compounds can cause a mild reaction called "metal fume fever," "brass chills,", "oxide shakes" and other colorfully descriptive illnesses. Zinc chloride irritates the mucosa probably because HCl is liberated from hydrolysis, All these symptoms readily disappear when airborne zinc is controlled.

Small amounts of zinc have a metallic taste and can cause illness and digestive tract disorders. Small amounts of concentrated zinc peroxide or permanganate can also cause localized tissue inflamation. The highly toxic properties of cyanides are detailed in profiles on cyanide compounds (84, etc.).

Skin contact with these compounds may result in rare and minor symptoms of zinc poisoning, but in general the epidermis is resistant to zinc compounds and any localized disorders are most likely to be caused by the anion.

The recommended Threshold Limit Value (TLV) for zinc chloride fume is 1 mg per cubic meter of air.[0225] The drinking water standards have been set at 15 mg per liter. The recommended, continuous exposure concentration in air of all these compounds is 0.01 mg per cubic meter of air.

3. OTHER HAZARDS

Zinc nitrate, zinc peroxide and zinc permanganate are moderately strong oxidizers. They should not be allowed to contact reducing material or a fire could result. Zinc cyanide when brought into contact with heat or acids could evolve deadly hydrogen cyanide gas. No other hazards have been found to exist.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage and Transportation

The zinc compounds, with the exception of the cyanide, can be handled with relative ease. These materials should be handled and stored in a well ventilated area. The containers should not be agitated when open, and when stored, should be sealed to prevent the hazard of airborne particles. For handling information on zinc cyanide, the Profile Reports on cyanide compounds should be consulted (84, etc.). These compounds are shipped under a variety of DOT, Coast Guard, and IATA regulations. The nitrates, peroxides and permanganates are classed as oxidizing materials and require yellow labels. The producers of these materials can supply details on container information but in general fiber drums are sufficient for these materials.

Disposal/Reuse

The USPHS Drinking Water Standards recommend a maximum zinc content of 15 mg/l. However, concentrations toxic to fish have been reported from 0.3 to 4 mg/l depending on hardness.[1752] Discharge of zinc compounds in the air should be controlled to the extent that the levels in the air surrounding the discharge point will not exceed 0.01 mg per cubic meter of air (as zinc). Zinc cyanide has much stricter limits due to the anion constituent. The maximum limit for cyanide in water (man and fish) is 0.01 mg per liter (ppm).

Zinc chloride and zinc cyanide can be recovered from plating operations or other processes when the waste stream is segregated or free from other contaminants. However, the proportion of firms who are recovering zinc is estimated to be small.[2350] The commercial applications of zinc nitrate peroxide and permanganate indicate that they will be consumed, or transformed to the degree that they are no longer easily recoverable. However, the use of sulfides to precipitate pigment grade zinc sulfide from zinc-containing waste streams should always be considered whenever it is technically possible and economically justifiable.[2359,2361]

5. EVALUATION OF WASTE MANAGEMENT PRACTICES

Option No. 1 - By-Product Recovery and Recycling

Effluent streams from industries such as metal finishing and electroplating often contain zinc wastes that can be readily recovered as a by-product. Equipment which can be utilized to concentrate a stream for reuse include reverse osmosis, multiple effect evaporation, and ion exchange. In some cases usable water is also recovered. Precipitation of zinc sulfide, a useful pigment, is also possible. Recycling of zinc cyanide eliminates an expensive waste treatment process. Recycling and by-product recovery is an acceptable and favored treatment option inasmuch as it reduces overall waste loads.

Option No. 2 - Destructive Precipitation

The use of lime, soda ash and similar materials to render waste streams alkaline,leading to the precipitation of heavy metal hydroxide sludges,is in widespread use today. The sludges present a handling and disposal problem which has been previously discussed in profiles on the chromates, nickel compounds, copper compounds,(21, 22, etc.). The procedure produces effluents with satisfactory zinc levels and is adequate for waste streams where recovery is not feasible.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The treatment of zinc compounds can be carried out adequately at the site of generation and hence the need for centrally treating these compounds is not indicated. A facility for destructive precipitative by pH adjustment has been recommended for the treatment of wastes generated within National Disposal Sites. This facility could also be used to handle non-routine shipments of zinc wastes to National Sites.

7. REFERENCES

0225. Threshold limit values for 1971. Occupational Hazards, Aug. 1971. p. 35-41.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 1,251 p.

1492. Merck index of chemicals and drugs. 7th ed. Rahway, New Jersey, Merck Company Inc., 1960. 1,634 p.

1570. Weast, R. C., ed. Handbook of chemistry and physics. 48th ed. Cleveland, Chemical Rubber Company, 1969. 2,100 p.

1752. Public health drinking water standards. U.S. Department of Health, Education, and Welfare, Public Health Service Publication No. 956, Environmental Control Administration, Rockville, Maryland, 1962.

2350. Personal communication. Don Hutchinson, Harshaw Chemical Company, to J. F. Clausen, TRW Systems, Sept. 26, 1972.

2359. Personal communication. George Kurma, Lucidol Division of Pennwalt Corporation, to J. F. Clausen, TRW Systems, Oct. 3, 1972.

2360. Personal communication. Jim Anderson, J. T. Baker Chemical Company, to J. F. Clausen, TRW Systems, Oct. 3, 1972.

2361. Personal communication. Mrs. C. E. Anderson, Carus Chemical Company, to J. F. Clausen, TRW Systems, Oct. 3, 1972.

2377. Mathewson, C. H., ed. Zinc: the science and technology of the metal, its alloys and compounds. New York, Reinhold Publishing Corp., 1959. 721 p.

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HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Zinc Chloride

IUC Name

Common Names Butter of Zinc(3)

Structural Formula

$ZnCl_2$

Molecular Wt. 136.30(1) Melting Pt. 262 C(1) Boiling Pt. 732 C(1)

Density (Condensed) 2.91 @ 25 C (1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

1 mm @ 428 C(1) @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 432 g/100 cc Hot Water 615 g/100 cc Ethanol 100 g/100 cc

Others: ether

Acid, Base Properties Aqueous solution is acid to litmus

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 0766
(2) 1570

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Zinc Cyanide

IUC Name

Common Names

Structural Formula

$Zn(CN)_2$(1)

Molecular Wt. 117.41(1) Melting Pt. dec. 800 C(1) Boiling Pt.

Density (Condensed) 1.852 @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.0005 g/100 cc @ 20 C(1) Hot Water Ethanol insoluble(1)

Others: soluble in alkalies, KCN, NH_3(1)

Acid, Base Properties basic in solution

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification Poison B, Label

Comments

References (1) 1570

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Zinc Nitrate Trihydrate

IUC Name ____________

Common Names ____________

Structural Formula

$Zn(NO_3)_2 \cdot 3H_2O$

Molecular Wt. 243.43(1) Melting Pt. 45.5 C(1) Boiling Pt. ____________

Density (Condensed) ____________ @ ____ ____ Density (gas) ____________ @ ____ ____

Vapor Pressure (recommended 55 C and 20 C)

____________ @ ____________ ____________ @ ____________ ____________ @ ____________

Flash Point ____________ Autoignition Temp. ____

Flammability Limits in Air (wt %) Lower ____________ Upper ____________

Explosive Limits in Air (wt. %) Lower ____________ Upper ____________

Solubility

Cold Water 327.3 g/100 cc @ 40 C(1) Hot Water ____________ Ethanol ____________

Others: ____________

Acid, Base Properties ____________

Highly Reactive with ____________

Compatible with ____________

Shipped in fiber drums - poly lined

ICC Classification oxidizing material, yellow label, 100 lb Coast Guard Classification same

Comments ____________

References (1) 1570
(2) 0766
(3) 1492

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Zinc Nitrate Hexahydrate

IUC Name

Common Names

Structural Formula

$Zn(NO_3)_2 \cdot 6H_2O$

Molecular Wt. 297.47(1)   Melting Pt. 36.4 C(1)   Boiling Pt. $\overset{-6H_2O}{105\text{-}131}$(1)

Density (Condensed) 2.065 g/cc @ 14 C(1)   Density (gas) ____ @ ____

Vapor Pressure (recommended 55 C and 20 C)

____ @ ____   ____ @ ____   ____ @ ____

Flash Point ____   Autoignition Temp. ____

Flammability Limits in Air (wt %)   Lower ____   Upper ____

Explosive Limits in Air (wt. %)   Lower ____   Upper ____

Solubility

Cold Water 184.3 g/100 cc @ 20 C(1)   Hot Water infinitely sol.(1)   Ethanol very soluble(1)

Others:

Acid, Base Properties solution is acid to litmus, pH of 5 percent aq. soln. is 5.1(3)

Highly Reactive with

Compatible with

Shipped in

ICC Classification oxidizing material, yellow label, 100 lb(2)   Coast Guard Classification same(2)

Comments

References (1) 1570
(2) 0766
(3) 1492

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Zinc Permanganate

IUC Name ____________

Common Names ____________

Structural Formula

$Zn(MnO_4)_2 \cdot 6H_2O$

Molecular Wt. 411.33(1)

Melting Pt. $-5H_2O$ @ 100 C(1)

Boiling Pt. ____________

Density (Condensed) 2.47 @ ____ ____

Density (gas) ____________ @ ____ ____

Vapor Pressure (recommended 55 C and 20 C)

____ @ ____ ____ @ ____ ____ @ ____

Flash Point ____________

Autoignition Temp. ____

Flammability Limits in Air (wt %) Lower ____________ Upper ____________

Explosive Limits in Air (wt. %) Lower ____________ Upper ____________

Solubility

Cold Water 33.3 g/100 cc(1) Hot Water very soluble(1) Ethanol decomposes(1)

Others: decomposes in acids(1)

Acid, Base Properties ____________

Highly Reactive with reducing agents

Compatible with ____________

Shipped in ____________

ICC Classification oxidizing mtl. yellow label, 100 lb(2)

Coast Guard Classification same

Comments Chrystaline form deliquesces(1)

References (1) 1570
(2) 0766

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Zinc Peroxide

IUC Name

Common Names ZPO, zinc superoxide

Structural Formula

$ZnO_2 \cdot 1/2H_2O$

Molecular Wt. 106.38(1) Melting Pt. $-O_2$ with vac.(1) Boiling Pt.*

Density (Condensed) 3.00(1) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water slowly decomposes(1) Hot Water decomposes(1) Ethanol decomposes(1)

Others: decomposes in ether, acetone(1)

Acid, Base Properties

Highly Reactive with heat or reducing materials(2) explodes at 212 C(2)

Compatible with (Not dangerous unless mixed with combustibles)(2)

Shipped in fiber drums, no liner required

ICC Classification yellow label oxidizing material, 100 lb Coast Guard Classification same

Comments Toxicity similar to ZnO

coml. prod. 50 to 60 percent ZnO_2 remainder is ZnO

*Decomposes above 150 C(3)

References (1) 1570

(2) 0766

(3) 1492

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HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Zinc Sulfide

IUC Name

Common Names Wurtzite(2)

Structural Formula

ZnS

Molecular Wt. 97.45(1)

Melting Pt. 1850 C @ 150 atm(1)

Boiling Pt. sublimes at(1) 1183 C

Density (Condensed) 4.087(1) @

Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point

Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water insoluble(1) Hot Water insoluble(1) Ethanol

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570
(2) 0766

PROFILE REPORT

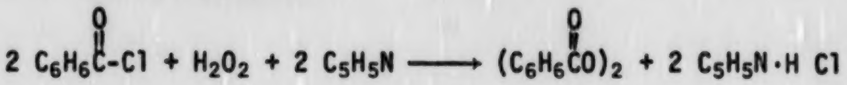
Benzoyl Peroxide (514)

1. GENERAL

Introduction

Benzoyl peroxide was first synthetized by B.C. Brodie in 1859. Commercial use began in the early 1900's when it was found that benzoyl peroxide was an effective bleaching agent for edible oils, and somewhat later, an excellent bleach for flour. Today, its major use is as a polymerization initiator for such polymers as polyethylene, polyvinyl chloride, polystyrene, polyester thermosets, polyacrylates, styrene-butadiene rubber and many others.[1433]

Benzoyl peroxide is prepared by treating benzoyl chloride with sodium peroxide or hydrogen peroxide in the presence of base such as pyridine or sodium hydroxide.



$$2\ C_6H_6\overset{O}{\overset{\|}{C}}\text{-}Cl + H_2O_2 + 2\ C_5H_5N \longrightarrow (C_6H_6\overset{O}{\overset{\|}{C}}O)_2 + 2\ C_5H_5N\cdot H\ Cl$$

Major manufacturers of benzoyl peroxide are:[1718,1790]

Penwalt Corp., Lucidol Div.,
1740 Military Rd., Buffalo, New York

Reichold Chemicals, Inc.
RCI Building, White Plains, New York

Tenneco Chemicals, Inc.
Modex Div., P.O.Box 2, Piscataway, New Jersey

U.S. Pexoggen, Div.Argus Chemical Corp.
850 Morton Ave, Richmond, California

Physical and Chemical Properties

The physical and chemical properties of benzoyl peroxide are included in the attached worksheet.

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2. TOXICOLOGY[0766,2351,2380]

The physiological effects of benzoyl peroxide have not been fully determined, therefore extra care should be exercised in its handling. Local affects include irritation, particularly to the eyes, nose and throat. The nature of systemic effects has not been investigated.

No Threshold Limit Value (TLV) has been established; it is, however, non-volatile and not handled in quantities that would cause dust problems.

3. OTHER HAZARDS

Benzoyl peroxide may decompose explosively when subjected to heat, shock or electrical discharge. The presence of organic material in benzoyl peroxide increases the hazard. Molten material will decompose instantly and explosively. Benzoyl peroxide is a powerful oxidizer and polymerization initiator, thus it can react with reducing agents and monomers to cause fire or explosion. These materials include alcohols, amines, various organic and inorganic acids, organic monomers and polymerization accelerators.[0766,1433,2380]

4. DEFINITION OF WASTE MANAGEMENT PRACTICES

Handling, Storage and Transportation

Benzoyl peroxide is packed in 1-lb or smaller fiber or paper containers that are either taped or glued shut. These are packed for shipment in wood or fiberboard boxes with each container surrounded by asbestos or fire-resistant cushioning of equal efficiency. Net weight of contents must not exceed 50 lb.[2380]

Benzoyl peroxide is also shipped with 30 to 50 percent water by weight since the addition of water considerably reduces all hazards. This material is packed in wood boxes containing polyethylene lined paper bags or aluminum drums with a maximum 1 lb dry weight capacity. Maximum gross weight must not exceed 200 lb. Wet material is also shipped in metal drums with polyethylene liners with a maximum gross weight of 350 lb.[0766,2380]

Shipping containers must have an ICC yellow Oxidizing Material label and preferably an approved MCA warning label. Trucks carrying over 2500 lb gross weight of material must be marked "DANGEROUS." The same label must be applied to rail cars carrying one or more packages of benzoyl peroxide.[2380]

Benzoyl peroxide is friction-, impact-, spark- and heat-sensitive. In addition, it is capable of reacting violently with many organic compounds. Thus,wooden boxes and metal containers should be opened with spark-resistant tools and only non-metallic instruments should be used to open fiber or paper containers. The material should be kept away from all sources of heat and electrical discharge. Grinding should only be done with extreme care with the proper diluents. Spills should be wiped up immediately with a soft brush or broom.[0766,2351,2380]

When storing benzoyl peroxide, all reasonable precautions must be taken to guard against fire and explosion hazards. It should be stored in minimum amounts in a cool place, out of direct rays of the sun, away from sparks, open flames and other sources of heat. Storage should be isolated from possible contact with acids, alcohols, ethers or other reducing agents or polymerization catalysts. Wet benzoyl peroxide must not be allowed to dry out.[0766,2380]

Use/Disposal

Benzoyl peroxide is used as a catalyst in various organic reactions and as a bleaching agent for oils and flour. The amounts used are normally very small in relation to the amount of the other materials. The by-products of reaction, usually benzoic acid, are not usually removed.[1433,2380]

Empty containers are normally examined to make certain that no material remains and then, if necessary, flushed with water to remove any residue and kept wet until they can be disposed of by incineration in an open incinerator. Waste benzoyl peroxide is stored wet until it can be destroyed with about ten times its weight of 10 percent sodium hydroxide solution. The reaction is only mildly exothermic and the final product, benzoic acid, may be flushed into the drain.[2380]

Recommended air and water standards have not been established at this time. Benzoyl peroxide is disposed of as benzoic acid for which the provisional limit for fish is 18 ppm.

5. EVALUATION OF DISPOSAL PROCEDURE

Option No.1 - Disposal of Empty Containers by Incineration

All cartons and bags should be examined to ascertain that they contain no residual benzoyl peroxide. Residual material, if present, should be flushed out with water. The empty cartons should be crushed and placed in a special collection drum. Keeping the contents of the drum moist is a good safety precaution. Periodically, the contents of the drum should carefully burned in a segregated area in an approved, open incinerator.

Option No.2 - Decomposition with Sodium Hydroxide

Unusable benzoyl peroxide is best stored wet until disposal. The slurry of waste material can be destroyed safely and easily by adding it slowly with stirring to ten times its weight of 10 percent sodium hydroxide solution. The reaction is only mildly exothermic. The final solution containing sodium benzoate, which is very biodegradable,[1543] may be flushed into the drain. Disposal of large quantities of solution may require pH adjustment before release into the sewer.

Option No.3 - Mixing with a Non-Combustible Material and Incineration

An equal weight of non-combustible material such as vermiculite or perlite can be added to a slurry of benzoyl peroxide. The excess water is then filtered off and the wet paste is carefully burned in an open incinerator. This method is suitable only for small quantities of material, since the non-combustible material may be discharged into the atmosphere.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Due to the hazards of shipping benzoyl peroxide and considering the ease with which wastes can be destroyed at the site of generation, this compound should not be considered a candidate for the National Disposal Site.

7. REFERENCES

0766 Sax, I.R., Dangerous properties of industrial materials. 3d ed. New York, Renhold Publishing Corporation, 1968. 1,251 p.

1433 Kirk-Othmer encyclopedia of chemical technology. 3d ed. 22 V. New York, Interscience Publishers, 1966.

1543 Ludzack, F.J., M.B. Ettinger. Chemical structures resistant to aerobic chemical stabilization. Journal Water Pollution Control Federation. 32(11):1173-1200, Nov. 1960.

1718 Synthetic organic chemicals, U.S. production and sales. U.S. Government Printing Office, Washington, D.C., Publication TC-479, 260 p.

1790 Chem. sources. 1970 ed. Flemington, New Jersey, Directories Publishing Company, 1969. 571 p.

2351 Baskin, A.D., Handling guide for potentially hazardous commodities, Chicago Railways Systems and Management Association, 1972.

2380 Benzoyl peroxide chemical safety data sheet, SD-81. Washington, Manufacturing Chemists Association, 1960. 10 p.

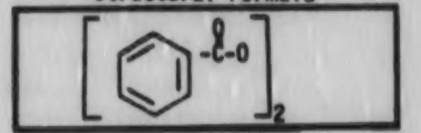
HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Benzoyl peroxide

IUC Name ______

Common Names dibenzoyl peroxide, benzoyl super oxide, Lucidol.

Structural Formula



Molecular Wt. 242.22 Melting Pt. 103-105 C(1) Boiling Pt. decomposes(1)

Density (Condensed) 1.3340 @ 25 C(3) Density (gas) ______ @ ______ ______

Vapor Pressure (recommended 55 C and 20 C)

______ @ ______ ______ @ ______ ______ @ ______

Flash Point ______ Autoignition Temp. 176 F(1)

Flammability Limits in Air (wt %) Lower ______ Upper ______

Explosive Limits in Air (wt. %) Lower ______ Upper ______

Solubility

Cold Water insoluble(2) Hot Water ______ Ethanol slightly(2)

Others: soluble in benzene, acetone, chloroform(2)

Acid, Base Properties neutral to slightly acid due to residual HCl(3)

Highly Reactive with reducing agents possibly resulting in fire(1,3)

Compatible with ______

Shipped in ______

ICC Classification Yellow-Label Oxidizing Material Coast Guard Classification yellow label

Comments may explode spontaneously; shock and friction sensitive(1,3)

References (1) 0766
(2) 1492
(3) 2380

PROFILE REPORT

1,2,4-Butanetriol Trinitrate (BTTN) (515)

1. GENERAL

BTTN is a liquid at room temperature that is a good gelatinizer for nitrocellulose. BTTN has been evaluated in the United States as a plasticizer for nitrocellulose but has not been used to any extent in this country. During World War II the Germans used BTTN to gelatinize nitrocellulose. BTTN is prepared by nitrating 1,2,4-butanetriol.[2169]

The physical/chemical properties for BTTN are summarized on the attached worksheet.

2. TOXICOLOGY

Because of its solubility in water and organic solvents which permits absorption, BTTN is more of a health problem than many of the other compounds containing nitro ester groups. BTTN can cause dilation of blood vessels, headaches, nausea, vomiting, methemoglobinemia, cyanosis, reduced blood pressure, central nervous system depression, coma and respiratory paralysis through ingestion, inhalation or skin adsorption.[0766]

3. OTHER HAZARDS

BTTN is a powerful explosive whose decomposition into gaseous products is accompanied by the evolution of large quantities of heat and a shock wave. BTTN is very sensitive to heat, friction and spark. Its impact sensitivity is about the same as for nitroglycerin (2 Kg weight, 15 cm with Bureau of Mines apparatus).[1147, 2169] The Brisance by Sand Test gives about the same results as nitroglycerin; 49 g vs 51.5g for nitroglycerin. The explosion temperature, 5-sec value, for BTTN is 230 C vs 220 C for nitroglycerin. It is more stable than nitroglycerin.[2169]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Details concerning manufacturing processes and waste streams from the manufacture of BTTN have not been found in the literature, but laboratory instructions for its preparation indicate that BTTN, if manufactured, would be prepared by the same processes as nitroglycerin and these processes would have similar waste streams. Details of nitroglycerin manufacture, handling and storage requirements are given in the Profile Report on Nitroglycerin (307). Because BTTN has about the same sensitivity to impact, heat and friction as nitroglycerin, it can be assumed that BTTN will not be transported beyond the plant in which it is manufactured. No BTTN should be discharged in a waste stream because of the explosive hazard created.

The Threshold Limit Value (TLV) for BTTN has not been established, but should be the same as that recommended for nitroglycerin-- 0.2 ppm. The recommended provisional limits should, similarly, be the same as those for NG-- 0.002 ppm for air, and 0.1 ppm for water.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

BTTN collected from spills and catch tanks, or considered unsuitable for use, should be disposed of by careful burning after absorption in sawdust, wood pulp or fullers earth. If BTTN is spilled on the ground, the contaminated ground should be removed with low impact tools and burned. Ignition of BTTN is usually accomplished by igniting a black powder squib placed on the surface. All burning is performed in a remote area.[1142] Although the products of combustion contain considerable NO_x, processes to control pollution from the products of combustion or BTTN and similar compounds are not in wide use.

Investigations are being conducted to develop better methods for the disposal of BTTN and similar compounds, including nitroglycerin, than the open-burning techniques currently used. These methods are based upon the use of scrubber-equipped incinerator systems for the controlled burning of explosive wastes, but this method is not available for wide use at this time. Additional research is required.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

BTTN is not normally a candidate for National Disposal Sites because it is not safe to transport, and facilities for its disposal are available at the sites where it would be manufactured. Disposal of BTTN at these facilities by open-burning is not a satisfactory technique. Controlled incineration in scrubber-equipped systems is recommended for disposal of BTTN wastes and waste gelatinized nitrocellulose containing BTTN. The BTTN wastes should be handled by a qualified ordnance disposal team.

7. REFERENCES

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 1,251 p.

1147. Department of the Army and Air Force, Military explosives, TM9-1910, Washington, Apr. 1955. 336 p.

2169. Fedoroff, B. T. Encyclopedia of explosives and related items. v. 2. Picatinny Arsenal, 1960.

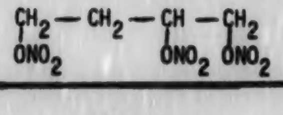
HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name 1,2,4-Butanetriol trinitrate

IUC Name 1,2,4-Butanetriol trinitrate

Common Names BTTN

Structural Formula



$\underset{ONO_2}{CH_2}-CH_2-\underset{ONO_2}{CH}-\underset{ONO_2}{CH_2}$

Molecular Wt. 231.06(1) Melting Pt. Boiling Pt.

Density (Condensed) 1.52g/cc @ 20 C(1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water slightly soluble Hot Water Ethanol miscible

Others: miscible with ether, acetone, and 2:1ether-ethanol

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Not shipped Coast Guard Classification Not shipped

Comments

References (1) 2169

PROFILE REPORT

Chlorates with Red Phosphorus (516)

1. GENERAL

Potassium chlorate is a very powerful oxidizing agent which in admixture with combustible materials forms a number of powerful explosives. Red phosphorus, a reducing material, is used in some of these explosive compositions. Mixtures used in toy pistol caps and toy torpedoes contain both potassium chlorate and red phosphorus. Two examples of these mixtures are as follows: (1) 67 parts potassium chlorate, 27 parts red phosphorus, 3 parts sulfur, and 3 parts calcium carbonate bound with an unspecified amount of "gum water", and (2) 61 parts potassium chlorate, 4 parts red phosphorus, 21 parts black antimony sulfide, 2 parts calcium carbonate, and 12 parts animal glue.[2169]

The physical/chemical properties for potassium chlorate and red phosphorus are summarized on the attached worksheets.

2. TOXICOLOGY

Potassium chlorate, like sodium chlorate (see Profile Report on Sodium Chlorate [385]) is not highly toxic, but ingestion or excessive inhalation of dust should be avoided. Prolonged exposure to chlorate dust may cause skin irritation to the mucous membrane of the eyes, nose and throat.[2123] Red phosphorus is considered relatively non-poisonous and is much less reactive than white phosphorus. The other components of these mixtures are generally considered non-poisonous.

3. OTHER HAZARDS

Potassium chlorate and red phosphorus mixtures, when confined, are so sensitive to electrical discharge, heat, friction, and impact that they undergo detonation when subjected to a very mild electrical, mechanical

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or thermal shock from a spark, flame or percussion. These mixtures cannot be stored under water prior to use because potassium chlorate is soluble and will be extracted from the mixture.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Relatively small quantities of cap and torpedo mixtures are manufactured and are not shipped prior to formulation into the end products. The sensitivity of these mixtures requires that excess and scrap material from fireworks charging operations be stored under water until destroyed by burning. Caps are described as "toy caps" and are shipped according to DOT regulations for Explosives, Class C,[2170] if the indiviudal caps each contain less than 0.25 grains of the explosive mixture. "Torpedoes, cap" are commonly packed in sawdust in pasteboard cartons and are described as special fireworks. They are shipped as Explosives, Class B(2382) if they contain less that 1/2 grain of $KClO_3$ - P mixture, or less than 4 grains of $KClO_3$, Sb_2S_3 and P mixture.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Option No. 1 - Detonator Destruction Furnace

The approved method referenced in the Ordnance Safety Manual for the destruction of detonators and primers may be used for torpedoes containing chlorate-phosphorus mixtures. In this method the components are fed to the combustion chamber of a specially designed detonator destruction furnace by means of a channel chute and a special conveying device.[2170] Scrubbers are employed to remove toxic fumes and dusts such as NO_x, P_4O_{10}, HCl, SO_2, and metal oxides.

Option No. 2 - Burning Pit Detonation

Torpedoes and caps in large quantities are detonated by burning in pits by applying heat from a fire. The devices are placed on top of a flammable substance such as straw and the flammable substance is ignited by means of a squib. Other explosives must be kept behind a barricade with overhead protection during destruction operations and located at a distance that assures safety. Personnel should be similarly shielded.[1147,2170] This destruction process is not satisfactory because individual components may not detonate and will constitute a personnel hazard during clean-up and because NO_x, metal oxides, P_4O_{10}, SO_2 and hydrogen chloride will be liberated during the destruction process on an uncontrolled basis.

Option No. 3 - Controlled Incineration (Municipal and Plant Incinerators)

Potassium chlorate mixtures, toy torpedoes and toy caps which have been properly marked to permit due precautions in handling can be destroyed safely by burning in municipal or plant incinerator systems equipped with scrubbing and mist removal systems. The incinerators should be fed by automatic conveyor devices, and the scrubber effluent should be neutralized and processed in a standard secondary treatment sewage system before discharge. This technique is recommended for disposal of the mixtures and devices.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Plants manufacturing torpedoes and caps which contain potassium chlorate and red phosphorus mixtures have facilities for the disposal of such mixtures. Devices which are not processed for disposal at such manufacturing facilities are not candidates for National Disposal Sites. The process to be employed for disposal should be Option No. 3, as recommended in Section 5. Surplus, scrap or obsolete materials should be handled by experienced plant personnel or other qualified ordnance demolition personnel.

7. REFERENCES

1416. Ross, A. and E. Ross. Condensed chemical dictionary. 6th ed. New York, Reinhold Publishing Corporation, 1961. 1,256 p.

1141. Department of the Army and the Air Force. Military explosives, TM-1910. Washington, Apr. 1955. 336 p.

2123. Manufacturing Chemists' Association. Chemical safety data sheet SD-42. Washington, 1952. 1 p.

2169. Tedoroff, G. J. Encyclopedia of explosives and related items. v. 1. Picatinny Arsenal, 1960. 692 p.

2170. Ordnance Corps. Department of the Army. Ordnance safety manual, ORDM7-224. Washington, 1951.

2382. Association of American Railroads, Bureau of Explosives. B. E. Pamphlet 7. General information relating to explosives and other dangerous articles. Washington, 1972. 87 p.

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Phosphorus, red

IUC Name

Common Names

Structural Formula

P_4

Molecular Wt. 124.08 (1) Melting Pt. Boiling Pt.

Density (Condensed) 2.34 g/cc @ 20 C (1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp. 260 C

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility (1)

Cold Water Insoluble Hot Water Insoluble Ethanol Insoluble

Others: Insoluble all solvents

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification flammable solid (1) Coast Guard Classification inflammable solid yellow label

Comments

References (1) 1416

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Potassium Chlorate

IUC Name Potassium Chlorate

Common Names

Structural Formula

$KClO_3$

Molecular Wt. 122.55 (1) Melting Pt. 368 C (1) Boiling Pt. 400 C decomposes (1)

Density (Condensed) 2.337 g/cc @ 20 C (1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility (1)

Cold Water Soluble Hot Water Soluble Ethanol Slightly soluble

Others:

Acid, Base Properties

Highly Reactive with reducing substances (1)

Compatible with

Shipped in drums (1)

ICC Classification oxidizing material (1) Coast Guard Classification oxidizing material (1)

Comments

References (1) 1416

PROFILE REPORTS ON

Copper Chlorotetrazole (518), Gold Fulminate (fulminating gold) (526), Silver Styphnate (539), Silver Tetrazene (540)

1. GENERAL

The compounds copper chlorotetrazole, gold fulminate, silver styphnate and silver tetranzene are described in the unclassified literature only to the extent that they can be prepared.[2171,0474] Copper chlorotetrazole is classified as a sensitive primary explosive.[0474] Other fulminates, styphnates, and tetrazene salts are vigorous primary explosives capable of being used as initiators, and it is therefore assumed that gold fulminate, silver styphnate, and silver tetrazene will have similar properties. The worksheets summarizing physical/chemical properties and the section on toxicology are not presented for these compounds because this data is not available.

2. TOXICOLOGY

It should be noted that copper, gold and silver compounds are in general, only slightly toxic, and that isocyanates and styphnates have variable toxicity. No other data is available on the specific toxicology of the subject compounds.

3. OTHER HAZARDS

The four compounds discussed in this Profile Report are believed to be so sensitive to heat, impact, electrical discharge, and friction that they undergo detonation when subjected to a very mild thermal, mechanical, or electrical shock by a spark, flame, or percussion.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

If the four compounds discussed are manufactured, waste from precipitation and washing operations should be collected in settling tanks for treatment by the processes described in Section 5. Excess material should also be disposed of in the same manner. All waste should be kept wet until treated.

Though these compounds are not classified by DOT it appears they would be classified as an Explosive, Class "A" and would be classified by the Army as Class 9, Group M explosives.[2170,0474]

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

These four compounds are not manufactured at present, and specific disposal procedures have not been published. With some modifications, the procedures used for the disposal of other detonating agents can be employed.

Option No. 1 - Detonation

The Ordnance Safety Manual recommends detonation as the best method for disposal of all initiating explosives.[2170] In the use of this procedure, bags containing the wet explosive are transported to the demolition area. Several bags are removed from the container and carried to the destruction pit, placed in intimate contact with each other, and a blasting cap placed between the bags to initiate the explosives. All remaining explosives should be kept behind a barricade with overhead protection during destruction operations. In the use of this method, the copper, gold, or silver present cannot be recovered, but will be lost to the soil in the demolition area. This method is not environmentally acceptable and should not be used unless the hazards of transportation and handling for disposal via the technique of Option No. 2 outweigh the ecological impact of detonation.

Option No. 2 - Controlled Combustion

The most promising technique under development for disposal of high explosives is the controlled combustion process which employs a rotary kiln incinerator equipped with appropriate scrubbing devices. This technique can probably be used with these four compounds. The explosive is fed to the incinerator as a slurry in water, at a weight ratio, explosive to water, of 1:3. The scrubber effluent would require treatment for recovery of particulate copper, gold or silver compounds formed as a combustion product. Additional copper, gold or silver could be recovered from the incinerator. This process is recommended for disposal of the four compounds being discussed.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The four compounds discussed, if used, would be used as initiating agents in military ammunition. Military ammunition manufacturing plants and ammunition storage depots have facilities for disposal of explosives discharged as scrap, or as contaminants of other wastes. Explosives which are not processed for disposal at such facilities are candidates for National Disposal Sites if the specific waste can be handled and transported safely. The explosives should be transported wet in a vehicle specially equipped for the safe transport of primary explosives, and only to the nearest disposal site. The disposal process to be employed at National Disposal Sites should be that cited as Option No. 2 in Section 5. Wastes of the compounds, and wastes contaminated with the compounds should be handled only by a qualified ordnance demolition team experienced in handling primary explosives. If hazards to the team and public from transportation and handling are deemed excessive by the demolition team, the waste should be disposed of by detonation in a cleared area.

7. REFERENCES

2170. Ordnance Corps., Department of the Army. Ordnance safety manual, ORDM7-224. Washington, 1951.

2171. Urbanski, Todeusz. Chemistry and technology of explosives, v. 1, 2, 3. Warszawa, Polish Scientific Publishers, 1967. Translated by Jurecki, Martin, New York, Pergamon Press.

PROFILE REPORT

Glycerol Monolactate Trinitrate (GLTN) (524)

1. GENERAL

GLTN is a powerful, high brisance, liquid explosive with many of the properties of nitroglycerin. The first step in preparation is to esterify glycerol with lactic acid by prolonged heating of a glycerol lactic acid mixture containing 4 percent excess lactic acid. The resulting mixture is then nitrated with a 40:60 mixture of nitric and sulfuric acids maintained at 20 C. Crude GLTN is extracted from this reaction product with ether, neutralized with sodium bicarbonate, washed, and dried with calcium chloride. The product contains about 5 percent nitroglycerin because it is not considered practical to prepare pure GLTN. GLTN is used as a gelatinizer for nitrocellulose.[0474]

The physical/chemical properties for GLTN are summarized in the attached work sheet.

2. TOXICOLOGY

GLTN like nitroglycerin, which is present in GLTN, can cause dilation of blood vessels, headaches, nausea, vomiting, methemoglobinemia, cyanosis, reduced blood pressure, central nervous system depression, coma and respiratory paralysis through inhalation, ingestion or skin absorption. Alcoholic beverages aggravate the health hazard. A Threshold Limit Value (TLV) for GLTN has not been established, but the TLV of 0.2 ppm for nitroglycerin would appear to apply to GLTN.[1142] Provisional limits for air, on the same basis, are 0.002 ppm.

3. OTHER HAZARDS

GLTN is a high explosive that is so sensitive to heat and impact that it undergoes detonation, if confined, when subjected to very mild thermal or mechanical shock by a flame or percussion. It will explode when heated to 223 C.[0474] The material should be handled only by experienced explosive ordnance personnel.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

As in the manufacture of nitroglycerin, wash waters and acid nitrating solutions used in GLTN manufacture must be stored until all GLTN has been decomposed by acid hydrolysis.[0474] Recovery and recycling of the spent acid is possible, after the GLTN has decomposed. Because GLTN is a high explosive it is recommended that no GLTN be released to the environment.

GLTN is stored as a liquid under the DOD regulations for a Class 9 Explosive.[0474] It is not normally shipped as such outside the boundaries of the plant in which it is manufactured. No DOT classification has been assigned to GLTN, and it cannot be shipped via common carrier.

5. EVALUATION OF CURRENT AND NEAR FUTURE GLTN DISPOSAL PROCESSES

GLTN which is collected from spills and catch tanks, and that which is considered unsuitable for use (contaminated or unstable to KI test), is currently disposed of by absorption in sawdust, wood pulp or fullers earth, after which it is carefully burned in an open burning area used for explosives disposal. If GLTN is spilled on the ground, the contaminated ground is removed with low-impact tools and burned. Ignition of GLTN is usually accomplished by placing a black powder squib on the surface of the absorbed GLTN. As expected, the products of combustion contain considerable NO_x. This method of disposal is not satisfactory unless, due to the specific character of the waste undergoing treatment, the safety hazards of disposal via the techniques being developed exceed the environmental impact of the NO_x generated by open burning.

Methods currently under investigation for minimum environmental impact, low hazard disposal of nitroglycerin are potentially applicable to the disposal of GLTN. Bacterial degradation and controlled incineration, with after burners and scrubbing for abatement of NO_x, are two techniques being investigated. Neither of these methods is available for use on GLTN at this time. Additional research is required.

GLTN wastes should be handled only by experienced ordnance disposal personnel with a background in GLTN or nitroglycerin disposal.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

GLTN is not a candidate for National Disposal Sites, in wastes other than gelatinized nitrocellulose. GLTN, as such, is not normally transported or used outside the complexes where it is manufactured, and facilities for its disposal are available at the sites of manufacture. It is anticipated that GLTN wastes other than gelatinized nitrocellulose will continue to be treated at these facilities. Gelatinized nitrocellulose, as noted in Profile Report (523), is a candidate for controlled incineration at National Disposal Sites.

7. REFERENCES

0474. Tomlinson, W. R., Jr. revised by O. E. Sheffield. Properties of explosives of military interest. Technical Report No. 1740, Rev. 1, Pictinny Arsenal, 1958. 348 p.

1142. JANAF Hazards Working Group. Chemical rocket propellant hazards. v.2. CPIA Publication No. 194, Silver Springs, Maryland. May 1970.

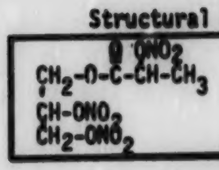
HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Glycerol Monolactate Trinitrate

IUC Name

Common Names GLTN

Structural Formula



$CH_2-O-\overset{O}{C}-\overset{ONO_2}{CH}-CH_3$
$CH-ONO_2$
CH_2-ONO_2

Molecular Wt. 299(1)   Melting Pt.   Boiling Pt. explodes(1) 223 C

Density (Condensed) 1.47g/cc @ 23 ° C   Density (gas) @ °

Vapor Pressure (recommended 55°C and 20°C)

@ °   @ °   @ °

Flash Point °   Autoignition Temp. °

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility

Cold Water 0.01g/100g at 25 C(1)   Hot Water <0.015(1) g/100g at 60 C   Ethanol

Others: miscible with ether, ether-alcohol, acetone(1)

Acid, Base Properties

Highly Reactive with Hydrolysis takes place in acid solution(1)

Compatible with

Shipped in

ICC Classification not shipped(1)   Coast Guard Classification not shipped(1)

Comments

References (1) 0474

PROFILE REPORT

Hydrazine Azide/Hydrazine(527)

1. GENERAL

Hydrazine is widely used as a mono-propellant in rocket engines where the hydrazine is decomposed to expanded volume gaseous products by passage over a catalyst bed. One of the disadvantages of hydrazine is that it has a relatively high freezing point (1.5 C). Blends of hydrazine azide and hydrazine have lower freezing points than hydrazine and these blends improve performance (Specific Impulse). The lowest freezing point (-17.5 C) is obtained for the blend containing 77 percent hydrazine by weight.[2338] It is this blend that will be discussed in this Profile Report.

Hydrazine azide/hydrazine blends may be prepared by at least three methods. The first method involves the reaction of sulfuric acid with sodium azide to form hydrazoic acid which is discharged into hydrazine to form hydrazine azide. The second method involves the metathesis of sodium azide and hydrazine sulfate to form hydrazine azide and sodium sulfate. The third method involves the reaction of butyl alcohol and sodium azide to give hydrazine azide and C_4H_5OHNa.[2169,2238] The first method is preferred, since the hydrazine azide is prepared in an excess of hydrazine which makes the process very simple and eliminates waste streams.[2338] The third method was abandoned because of low yields and the second method gave a product contaminated with sodium sulfate that reduced the activity of decomposition catalyst beds.

Though small quantities of hydrazine azide/hydrazine blends have been prepared and shipped, it is doubtful that these blends will become an item of commerce because these blends have been found to be very corrosive to stainless steel.

The physical/chemical properties for a hydrazine azide/hydrazine blend containing 77 percent hydrazine are summarized on the attached worksheet.

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2. TOXICOLOGY

The toxicology of hydrazine azide/hydrazine blends has not been evaluated. Since hydrazine is the major component of the blends, it can be assumed that the toxicity will be at least equal to that for hydrazine (see Profile Report on Hydrazine [212]). A worker at TRW systems who inhaled the vapors from a 1-gram sample of a blend for a few minutes in the laboratory reported a detached feeling that left in about two hours. It is therefore recommended that exposure to inhalation and skin contact with vapors of the blends be avoided until the toxicity is defined. The provisional limit for air recommended is 0.01 ppm, and the provisional limit for water is set at 0.065 ppm.

3. OTHER HAZARDS

Hydrazine azide/hydrazine blends will present the same fire hazards as hydrazine. These are discussed in the hydrazine Profile Report. Impact tests indicate the binary system hydrazine azide/hydrazine is not sensitive to 120Kg-cm of shock with one exception. A detonation did occur on the second bounce when testing one sample saturated with hydrazine azide. Also, no detonation propagation could be demonstrated for the blends.[2338]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Adequate procedures for the safe handling, transportation and storage of the blends have not been defined because the blends are regarded as an experimental material. On one occasion 10-lb quantities in a polyethylene container packed in a wooden box were shipped as a Corrosive Liquid under a White Label. Because hydrazine azide/hydrazine blends attack stainless steel, it is doubtful that additional quantities will be shipped for evaluation as a monopropellant.

Personnel who are required to handle wastes containing or contaminated with hydrazoic acid-hydrazine blends should wear rubber protective clothing, and use forced air supply respiratory equipment. Hydrazine azide/hydrazine blends will probably be encountered only as excess or contaminated material. Discharge of any material to the environment should be avoided until the toxicity is understood.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Because blends of hydrazine azide/hydrazine are an experimental material, disposal processes have not been established. It is recommended that material be disposed of by incineration. The blends should be diluted with water and sprayed into an incinerator with a scrubber similar to that used for hydrazine (see Profile Report on Hydrazine [212]).

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Because only experimental quantities of hydrazine azide/hydrazine blends have been prepared, it is not likely that any of the blends will be sent to National Disposal Sites for disposal. If at some future date the blends are manufactured, then wastes containing the blends will be candidates for National Disposal Sites. The techniques for disposal, as discussed in Section 5, will be similar to those used for disposal of hydrazine wastes.

7. REFERENCES

2169. Fedoroff, B. T. Encyclopedia of explosives and related items. v.1. Picatinny Arsenal, 1960. 692 p.

2338. Rockenfeller, J. D. Development of improved monopropellants, AFRPL-TR-70-108. East Hartford, Connecticut, United Aircraft Corporation, 1970. p 29.

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Hydrazine Azide/Hydrazine

IUC Name Hydrazinium Azide/Hydrazine

Common Names

Weight ratio: 77 parts N_2H_4, 23 parts N_5H_5

Structural Formula

$N_5H_5-N_2H_4$

Molecular Wt. a blend not a compound(1) Melting Pt. -17.5C(1) Boiling Pt.

Density (Condensed) 1.083 g/cc @ 25 C(1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

7.7 torr @ 20 C(1) 23.5 torr @ 40 C(1) 520 torr @ 55 C(1)

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water soluble(1) Hot Water soluble(1) Ethanol slightly soluble(1)

Others:

Acid, Base Properties

Highly Reactive with oxidizing agents(1)

Compatible with glass, polyethylene(1)

Shipped in polyethylene enclosed in a wood box(1)

ICC Classification corrosive liquid(1) Coast Guard Classification -

Comments Experimental monopropellant, not produced commercially

References (1) 2338

PROFILE REPORT

Lead 2,4-Dinitroresorcinate (LDNR) (530)

1. GENERAL

Lead 2,4-dinitroresorcinate is a less powerful explosive and a less efficient initiator than lead styphnate. It is unusually sensitive to friction or stab action without being unduly sensitive to impact, therefore, it is suitable for use as a priming material. It is prepared by treating lead nitrate in hot aqueous solution with a boiling solution of dinitroresorcinol to which a stoichiometric quantity of sodium carbonate has been added. After cooling, the precipitated lead dinitroresorcinate is washed with water, alcohol, and ether before being dried.

LDNR has the same order of sensitivity to impact as dextrinated lead azide, but it is much less sensitive to thermal shock. When lead dinitroresorcinate is exposed to a flame, it deflagrates, but does not explode with the violence of lead styphnate.

The relative difficulty involved in its manufacture and the difficulty in controlling the crystals to a small size for safe handling has limited the use of lead dinitroresorcinate. It has been used in only special designs of ammunition and in electric detonators.[0474,1433]

The physical/chemical properties for 2,4-lead dinitroresorcinate are summarized on the attached work sheet.

2. TOXICOLOGY

Lead 2,4-dinitroresorcinate is insoluble in water and organic solvents and has a very low vapor pressure which lessens the possibility of its being absorbed through the skin or by vapor inhalation. Inhalation of the dust or

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ingestion of LDNR should be avoided because of the possibility of lead poisoning (see Profile Report on Lead, [233]) and adverse reaction to the nitro groups. Exposure limits have not been established for lead 2-4-dinitroresorcinate.[0225,0776]

3. OTHER HAZARDS

Lead dinitroresorcinate is a primary explosive and detonating agent that is so sensitive to electrical discharge, impact, and friction that it undergoes detonation when subjected to very mild mechanical or electrical shock by percussion or electrical discharge. Because of their extreme sensitivity, and the high degree of explosive hazard, wastes containing lead dinitroresorcinate should be handled only by an experienced explosives and ordnance disposal team. Normal procedures are to handle lead dinitroresorcinate as a slurry in water to minimize hazards.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

The sensitivity of 2,4-dinitroresorcinate to shock and friction, as with most initiating agents, requires that all scrap and waste from preparation and purification be maintained wet for destruction. Lead, 2-4-dinitroresorcinate is packaged wet for storage and shipment. Packaging is accomplished by placing approximately 25 lb, wet with 20 percent water or a 50:50 water-alcohol mixture for low temperature storage, in a duck-or rubberized-cloth bag covered with a cap of the same material. The bag is then tied securely. Not more than six such bags are placed in a large bag of the same material. The large bag is tied and placed in the center of a watertight metal or wooden barrel, drum, or keg lined with a heavy close-fitting jute bag. The large bag containing lead 2,4-dinitroresorcinate is surrounded with well-packed sawdust that has been saturated with water or water-ethanol mixture. The bag forming a liner is sewn closed before closing the barrel, drum, or keg. Not more than 150 lb of initiating explosive is permitted in a single container. It is shipped wet under DOT regulations for an Explosive, Class A.[1147]

Because lead 2,4-dinitroresorcinate is a sensitive high explosive, it is recommended that no lead 2,4-dinitroresorcinate be released to the environment.

5. EVALUATION OF CURRENT AND NEAR FUTURE LEAD 2,4-DINITRORESORCINATE DISPOSAL PROCESSES

Option 1 - Detonation

Lead 2,4-dinitroresorcinate is usually disposed of by detonation. Wet bags in the transporting container (described in Section 4) are transported to the disposal area. Then several bags are removed from the transporting container, carried to the destruction pit, placed in intimate contact with each other, and blasting caps are placed between the bags to initiate the lead 2,4-dinitroresorcinate. Remaining explosives must be kept behind a barricade with overhead protection during the destruction operations and located at a distance that assures safety. Personnel must be behind a similar barricade.[1174,2170] The destruction pit by necessity must be in a remote location that should be located in alkaline soil or soil treated with lime in order to avoid contamination of ground water or streams with lead. Lead and NOx will be liberated to the environment. This technique is not regarded as satisfactory unless hazards to the disposal team and the public from disposal via Option 2 outweigh the ecological impact.

Option 2 - Controlled Combustion

The most promising technique under development for disposal of lead dinitroresorcinate and other high explosives is the controlled combustion process, which employs a rotary kiln incinerator equipped with appropriate scrubbing devices. The lead dinitroresorcinate is fed to the incinerator as a slurry in water, at a weight ratio, explosive to water, of 1:3. The scrubber effluent then requires treatment for recovery of the particulate lead oxide formed as a combustion product. This process is recommended for the disposal of lead dinitroresorcinate.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Lead dinitroresorcinate is used to a limited extent in special designs of ammunition as a primary explosive and in electric detonators. Military ammunition manufacturing plants and ammunition storage depots have facilities for disposal of lead dinitroresorcinate discharged in waste streams as scrap, or as a contaminant of other wastes. Those wastes that are not processed for disposal at such facilities are candidates for National Disposal Sites if the specific waste can be handled and transported safely. The waste should be transported wet in a vehicle specially equipped for safe transport of primary explosives and only to the nearest disposal site. The disposal process to be employed at National Disposal Sites should be that cited as Option 2 in Section 5. Lead dinitroresorcinate and wastes contaminated with lead dinitroresorcinate should be handled only by a qualified ordnance demolition team experienced in handling lead dinitroresorcinate. If hazards to the team and the public from transportation and handling are deemed excessive by the demolition team, the waste should be disposed of by detonation in a cleared area.

7. REFERENCES

0225. American Conference of Government Industrial Hygienist. Threshold limit values for 1971. Occupational Hazards, p. 35-40. Aug. 1971

0474. Tomlinson, W. R. Jr., revised by O. E. Sheffield. Properties of explosives of military interest. Technical Report No. 1740, Rev. 1, Picatinny Arsenal. Apr. 1958. 349 p.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed., New York, Reinhold Publishing Corp. 1968. 1,251 p.

1147. Department of the Army and the Air Force. Military explosives. TM-9-1910, Washington. Apr. 1955. 336 p.

2170. Ordnance Corps, Department of the Army. Ordnance safety manual. ORDM-7-224, Washington. 1951

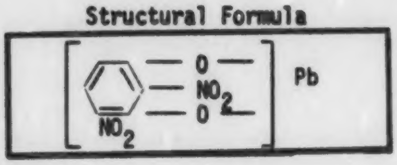
HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Lead 2,4-dinitroresorcinate

IUC Name Lead 2,4-dinitroresorcinate

Common Names

Structural Formula



Molecular Wt. 405(1)

Melting Pt. 265 C explodes(1)

Boiling Pt.

Density (Condensed) 3.2 g/cc @ 25 C (1)

Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point

Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water Insoluble(1)

Hot Water Insoluble(1)

Ethanol Insoluble(1)

Others: Ether-insoluble(1)

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in Bags wet(1)

ICC Classification Explosive, Class A(1)

Coast Guard Classification Explosive Class A(1)

Comments

References (1) 0474

PROFILE REPORT

Nitrocellulose (534)

1. GENERAL

Nitrocellulose (cellulose nitrate, or NC) is a mixture obtained by nitrating cellulose. Cellulose is a long chain polymer of anhydroglucose units. The hydrogen of the three hydroxyl units in each glucose unit in cellulose can be replaced by NO_2 groups. The nitrogen content of cellulose tri-nitrate is 14.14 percent. Although complete nitration is difficult to accomplish, materials containing 14 percent nitrogen can be prepared without difficulty. The nitration is carried out under conditions of acid concentration, temperature, and time of nitration which depend upon the final product desired.

For the manufacture of military grad nitrocellulose, the DuPont mechanical dipper technique is normally used. One advantage of the mechanical dipper process is that the cellulose can be quickly submerged in the mixed acid and the evolution of nitrogen oxides reduced. Between 30 and 40 lb of dry, fluffed cellulose (cotton linters or wood pulp) is the normal batch size added to the nitrating dipper containing a large excess (about 1,600 lb) of mixed acid (mixed sulfuric and nitric acids) at 30 C. The composition of the mixed acid is adjusted to the grade of nitrocellulose required. For gun cotton (13.3 percent N) the normal composition with wood pulp is 59.5 percent sulfuric, 28.5 percent nitric, 3.0 percent nitrosylsulfuric and 9.0 percent water. The nitration reaction is exothermic, and the charge temperature is kept below 34 C by cooling. After about 25 minutes in the nitrator, the charge is transferred rapidly to a centrifuge, the spent acid removed and then the nitrated cotton is drowned in a large excess of water. The spent acid is pumped to a tank where part of it is fortified for reuse and the remainder is sent to the acid recovery plant. The crude nitrocellulose is usually pumped as a water slurry to the purification area where it goes through an alaborate series of water washes, boiling treatments, neutralizations and beating steps to stabilize the nitrocellulose. First, the acid content is reduced to a low level by washing. Then, the nitrocellulose receives several boiling treatments to destroy the unstable sulfate esters and nitrates of partially oxidized cellulose by acid hydrolysis. The nitrocellulose is water washed between boils. Next, the product is beaten in a Jordan refiner to reduce the fiber length and remove traces of occluded acid. Finally, the nitrocellulose is boiled and in dilute sodium carbonate solution, then washed with water until free of alkali. After purification, the NC is centrifuged for partial removal of water, and then processed in accordance with the specific end-use requirements of the batch. Nitrocellulose is used for military purposes in the manufacture of single base and double base propellants, a gun cotton, and commercially as collodion.[1142,1147]

Nitrocellulose fines recovered from the purification washing and centrifugation waste liquor sumps are generally destroyed by open burning. Some plants now recycle the recovered fines to production.

The physical/chemical properties of nitrocellulose are summarized in the attached work sheet.

2. TOXICOLOGY

Nitrocellulose presents no toxic hazard. However, when handling nitrocellulose wet with alcohol, the alcohol is usually denatured with 0.5 percent benzene which presents a benzene inhalation hazard.[1142]

3. OTHER HAZARDS

Dry nitrocellulose is very sensitive to impact, friction, heat and spark, and is an explosive hazard. Nitrocellulose wet with solvent is a dangerous fire hazard. Nitrocellulose wet with water is less dangerous. However, nitrocellulose can be detonated even when wet, if confined and initiated with a strong booster.[1142] Nitrocellulose has an impact sensitivity (2 Kg. wt) for 5 Mg sample of 8 cm., roughly equivalent to the sensitivity of DDNP-a sensitive initiator.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Wash waters containing nitrocellulose particles and other scrap created during manufacturing operations are collected in sumps. After settling nitrocellulose are collected, placed in drums under water and transported to the disposal area.[1142] Scrap propellant containing nitrocellulose, if free of aluminum powder, is also placed in drums under water and transported to the disposal area. If aluminum powder is present, the propellant containing nitrocellulose is stored dry because the aluminum reacts with water to produce hydrogen.

Dry nitrocellulose is classified by DOT as an Explosive, Class A. The weight limit per container is 10 lb of dry, uncompressed nitrocellulose. Wet nitrocellulose (colloided, granular, or flake) with 20 percent water is classed as a flammable solid. Wet nitrocellulose (colloided, granular or flake) with 20 percent alcohol or solvent is classed by DOT as a flammable liquid. The alcohol is usually denatured ethanol, isopropanol or normal butanol. At no time is the alcohol entirely uniform throughout the drum. On standing the alcohol gradually settles leaving the nitrocellulose on top with a lower alcohol content. Nitrocellulose undergoes very slow decomposition even at ordinary temperatures. Because of deterioration, nitrocellulose should be used within a few months after manufacture. Frequent stability checks (KI test) should be made if the NC has been stored over one year.[1142]

Because of its sensitivity, no nitrocellulose should be released to the environment in waste streams.

5. EVALUATION OF CURRENT AND NEAR FUTURE NITROCELLULOSE DISPOSAL PROCESSES

The processing options for the disposal of nitrocellulose are briefly described in the following paragraphs together with recommendations as to adequacy.

Option No. 1 - Disposal of Burning

Nitrocellulose for destruction is usually placed in fiberboard drums, metal drums or cans lined with a heavy-gauge leakproof liner and the nitrocellulose covered with water. The nitrocellulose is then transported to an approved burning ground. The NC wastes are placed on a noncombustible pad such as asbestos, the water allowed to drain off, and the NC wastes are then covered with a combustible material such as fuel oil. The flammable material is ignited by firing a black powder squib or other device placed in the wastes.[1142] Although the products of combustion contain considerable NO_x, better methods for disposal are not currently in wide use.

Option No. 2 - Controlled Incineration

Nitrocellulose wastes, and combustible materials contaminated with nitrocellulose are readily amenable to disposal via controlled incineration. Two types of equipment are currently in prototype use for the controlled combustion of explosive wastes. The first disposal system is similar to conveyor fed devices used as muncipal incinerators, operates on an induced draft, and is equipped with afterburner and scrubbing systems to abate NO_x and particulate emissions. The second type of equipment, similarly equipped with scrubbing systems for the abatement of NO_x and particulate emissions, is a rotary kiln incinerator, which is fed with a slurry of nitrocellulose in water, in a 1 to 3 ratio. The rotary kiln incinerator has secondary fuel oil or natural gas) burners. This method of disposal is preferred.

Option No. 3 - Reduction with Sodium Hydroxide

Small quantities of nitrocellulose are decomposed by adding it with agitation to five times its weight of a 10 percent solution of sodium hydroxide that has been heated to 70 C. Agitation is continued for at least 15 minutes after all the nitrocellulose has been added.[1147] The products this decompsoition process require additional treatment. After pH adjustment and dilution, the cellulose can be handled by a sewage treatment plant.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The major uses of nitrocellulose are in the manufacture of single and double base propellants and smokeless powder. The open burning which is widely used is not considered satisfactory for destroying the large quantities (millions of pounds) of excess or waste material containing nitrocellulose. Material containing nitrocellulose which is excess, contaminated or aged is a candidate for disposal at National Disposal Sites if the specific waste can be handled safely and transported safely. The methods for controlled incineration that were discussed in Section 5, Option No. 4 should be used for destroying excess material or wastes containing nitrocellulose at National Disposal Sites. Nitrocellulose for disposal should be transported under water, in a vehicle properly equipped for safe transport of flammable liquids to the nearest satisfactory disposal site. Surplus, scrap or obsolete material containing nitrocellulose should only be handled by qualified ordnance demolition personnel experienced in the disposal of explosives. If hazards to the disposal team and the public due to handling and transportation to the nearest National Disposal Site are deamed excessive by the demolition team, the material should be disposed of by burning in a cleared area.

7. REFERENCES

1142. JANAF Hazards Working Group. Chemical rocket propellant hazards. V 2. CPIA Publication No. 194, Silver Springs, Maryland. May 1970. 99 p.

1147. Department of the Army and Air Force. Military explosives, TM-1910. Washington, Apr. 1955. 336 p.

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Nitrocellulose

IUC Name Cellulose Nitrate

Common Names NC

Structural Formula

$[C_6H_{10}O_5(NO_2)_x]_n$

x = no of NO_2 groups

n = degree of polymerization

Molecular Wt.[1] 272.3(one unit)(1) Melting Pt.[2] 200 C in vac(1) Boiling Pt. decomposes(1)

Density (Condensed) 1.66 g/cc @ 23 C Density (gas) ____ @ ____ ____

Vapor Pressure (recommended 55°C and 20°C)

____ @ ____ ____ @ ____ ____ @ ____

Flash Point ____ Autoignition Temp. ____

Flammability Limits in Air (wt %) Lower ____ Upper ____

Explosive Limits in Air (wt. %) Lower ____ Upper ____

Solubility

Cold Water Insoluble(1) Hot Water Insoluble(1) Ethanol Insoluble

Others: Soluble acetone, organic nitro compounds(1)

Acid, Base Properties ____

Highly Reactive with ____

Compatible with ____

Shipped in Waterproof containers

ICC Classification Explosive, Class A(dry)(1) Coast Guard Classification Explosive Class A(dry)(1)

Comments ____

References (1) 1142

PROFILE REPORT

Polyvinyl Nitrate (PVN) (535)

1. GENERAL

PVN is an insoluble explosive which is not used because of its poor stability and because it cannot be placed into solution with a solvent.[0474,2169] If used, it would have some of the applications of nitrocellulose. PVN can be prepared by the nitration of polyvinyl alcohol with a mixture of nitric acid and acetic anhydride, or with a mixture of nitric acid and carbon tetrachloride. It is a readily flammable substance which burns without melting.

Since PVN is not manufactured or used, it has not received DOD storage and handling classifications, and shipping regulations covering the material have not been published. If it should be manufactured in the future, shipping, handling and disposal procedures should be similar to those for nitrocellulose (see Profile Report on Nitrocellulose, [534]).

The physical/chemical properties for PVN are summarized on the attached worksheet.

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2. REFERENCES

0474. Tomlinson, W. R., Jr., revised by O. E. Sheffied. Properties of explosives of military interest, Technical Report No. 1740, Rev. 1, Apr. 1958, Picatinny Arsenal. 348 p.

2169. Fedoroff, B. T., Encyclopedia of explosives and related items. v 1, Picatinny Arsenal, 1960. 692 p.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Polyvinyl nitrate

IUC Name

Common Names PVN

Structural Formula

$(C_2H_3NO_2)_n$

Molecular Wt. (89)n(1)   Melting Pt. 50 C (1)   Boiling Pt.

Density (Condensed) @   Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@   @   @

Flash Point   Autoignition Temp.

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility

Cold Water Insoluble(1)   Hot Water   Ethanol

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification None   Coast Guard Classification None

Comments Explosion temperature 265; has been produced only in the laboratory, for experimental use, because of its instability.

References (1) 0474

PROFILE REPORT

Smokeless Gunpowder (541)

1. GENERAL

The term "smokeless gunpowder" is used to describe a variety of propellant (low explosive) compositions generally used in projectile weapon service. The two broad types into which these compositions fall are single base propellant and double base propellant.

All current smokeless gunpowder compositions employ nitrocellulose as the major component. As indicated by its name, single base propellant contains nitrocellulose, and a relatively small amount of additives, plasticizers, and modifying agents. Double base propellant, as currently manufactured, is composed principally of nitrocellulose and nitroglycerin, with relatively small amounts of additives, plasticizers and modifying agents. Occasionally, other explosives have been used in addition to nitroglycerin. Two characteristic smokeless gunpowder products and the processes used to manufacture them are described below.

Single base, solvent extruded propellant is colloided nitrocellulose containing about 1 percent of diphenylamine to improve its storage life and a small amount of plasticizer (e.g., dibutyl phthalate). Modifying agents such as dinitrotoluene and certain inorganic salts are sometimes added in order to reduce the flash of the gun in which the powder is used and to minimize the hygroscopicity of the powder. The colloiding is usually accomplished by pumping ethyl alcohol through the wet nitrocellulose in a hydraulic press to remove the water (this makes a drying process unnecessary), adding ether, and macerating in a dough mixer. This combination of alcohol and ether reduces the nitrocellulose to a pulpy mass that may be extruded into rope or cut to a definite length to give powder grains. The solvent is removed from the grains by heating in vats under water, and the small amount of water remaining is removed by air drying.[1147]

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Ball powder is manufactured by a process whose first step is to charge nitrocellulose-in-water slurry into a still, where the NC is dissolved in ethyl acetate, stabilized with diphenylamine and neutralized with chalk. Nitroglycerin is added as a solute in the ethyl acetate fed to the still, when double base ball powder is to be produced.

The dissolved NC is dispersed into small spheres or balls by stirring under controlled conditions, adding a protective colloid (generally, animal glue) to prevent coalescence of the spheres. The solvent is boiled off and recovered, and the balls are screened into several size fractions and coated with a deterrent (such as dinitrotoluene) to control burning rate. Ball powder thus manufactured has been used interchangeably with conventional powder for loading small arms ammunition, both sporting and military, up to and including shells for 37 mm aircraft cannon. As noted in a TRW trip report (see Appendix D, Third Monthly Report) a mid-western location where ball powder had formerly been processed contained about ten million pounds of finely divided ball powder wastes in process water discharge sloughs and plant sewers.

The physical/chemical properties for smokeless gunpowder are not summarized on a worksheet since smokeless gunpowder does not have a definite composition.

2. TOXICOLOGY

The toxicology of each smokeless gunpowder composition is the sum of the toxicologies of the individual components. The reader is referred to the Profile Reports on Nitrocellulose [534], Nitroglycerin [307], and Dinitrotoluene [165].

3. OTHER HAZARDS

Smokeless powder is an explosive material which is principally a fire hazard. Its hygroscopicity requires that it be packaged in waterproof airtight containers. Smokeless powder was formerly packaged for storage in copper-lined wooden boxes, which held as much as 150 lb and were air-pressure tested for resistance to leakage before use.

Standard containers for smokeless powder are now made of stainless steel with a rubber-gasketed closure.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

The management of waste from smokeless powder is not much different than that for nitrocellulose. Smokeless gun powder, because of the stabilizer additives employed in its formulation, has an extremely slow degradation rate. For this reason, smokeless gun powder wastes remain explosive and fire hazards for prolonged periods of time. Smokeless powder fines which have been discharged in plant sewer outfalls, in addition to their flammable and explosive hazard potential, can be sources of atmospheric pollution through the evolution of NO_x if anaerobic fermentations take place in the receiving water course stream beds. Open burning of recovered smokeless powder fines produces large quantities of NO_x.

Proper waste management practices must eliminate the safety hazards and the environmental hazards cited above.

Smokeless powder is stored under DOD regulations for Explosives, Class 2 or Class 2A and is shipped under DOT regulations for Explosives, Class B.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Smokeless powder is disposed of by the same processes as nitrocellulose (see Profile Report on Nitrocellulose [534].

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Smokeless gunpowder is used to a major extent in loading small arms ammunition, both sporting and military, up to and including 37 mm. As indicated in Section 1 large quantities of ball powder waste (millions of pounds), both with and without dinitrotoluene added, have been found at one plant which indicates there is a probability that large quantities of smokeless gunpowder wastes require treatment. Open burning which liberates large quantities of NO_x cannot be considered a satisfactory process for disposal of smokeless gunpowder. When the processes for controlled incineration, discussed in the Profile Report on Nitrocellulose (534), are adequately developed, one of these methods should be used at National Disposal Sites for destroying smokeless powder wastes. Surplus and aged smokeless gunpowder can be reprocessed for recovery. If this is impossible or undesirable, smokeless gunpowder is a candidate for disposal at National Disposal Sites if the specific waste can be handled and transported safely. Smokeless gunpowder should be transported under water, in a vehicle properly equipped for safe transport of high explosives, and only to the nearest satisfactory disposal site. Surplus scrap or obsolete smokeless gunpowder should be handled by qualified ordnance demolition personnel experienced in the disposal of explosives. If hazards to the disposal team and public, due to handling and transportation to the nearest National Disposal Site, are deemed excessive by the demolition team, the material should be disposed of by burning in a cleared area.

7. REFERENCES

1147. Department of the Army and the Air Force. Military explosives, Tm9-1910, Apr. 1955, Washington. 336 p.

PROFILE REPORT

Hydrogen-3

1. GENERAL

Introduction

Tritium, an isotope of hydrogen, is produced in nuclear reactors in substantial quantities. It is currently released to the environment in the form of tritiated coolant water from the reactor and tritium wastes resulting from reprocessing of the nuclear fuels. Although it is one of the least hazardous radioactive nuclides, the recovery and retention of tritium will be required in the near future due to its long half-life for radioactive decay, the rapid rate of expansion in the nuclear power and fuel-reprocessing industries, and its ability to be metabolized in the form of tritiated water and incorporated into body fluids and tissues.

Tritium is produced in the fission of uranium-235 and plutonium-239 with yields of 0.01 percent and 0.02 percent, respectively. Tritium decays by the emission of a beta particle and an anti-neutrino to form stable helium-3. The half-life for this process is approximately 12.3 years. The average energy of the beta emitted by tritium is 5.6 Kev, which is only about one one-hundredth of the energy emitted by most other beta emitters.

The projected growth in production of this isotope will parallel that of the civilian nuclear power program. Present projections indicate that the total installed capacity of nuclear power plants will grow by a factor of 60 between 1970 and 1985.[2148] The expected annual production and accumulated wastes of hydrogen-3 (Figure 1) from the civilian nuclear power program are included.

Uses

Tritium is used in luminous devices, tagging, and fusion research.

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Sources and Types of Wastes

Tritium may be produced in nuclear reactors by one or more of the following five methods: fissioning of uranium, neutron capture reactions with boron and lithium added to the reactor coolant, neutron capture reactions with boron in control rods, activation of deuterium in water, and high energy neutron capture reactions with structural materials.[2378]

Fission-product tritium is generally contained by the cladding surrounding each fuel element. While small amounts of tritium were found in the past to leak to the primary coolant with the stainless-steel clad elements, the use of zirconium cladding has been found to limit the diffusion of tritium through the cladding to very low quantities. The fission-product tritium generated is contained until the fuel is reprocessed, when it appears as tritiated water in the reprocessing plant evaporator condensates. Additional sources of tritium are in the primary coolant loops of pressurized water reactors and high temperature gas-cooled reactors. In the pressurized water reactors, boric acid which is dissolved in the primary coolant for reactivity control causes the production of tritium by neutron capture reactions. The production of tritium occurs in high temperature gas cooled reactors by ternary fission and by activation of helium-3 found in trace amounts in the helium coolant. Although the primary coolant from these reactors is not routinely discharged to the waste disposal system, leakage of coolant from pumps and the water utilized during the refueling operation are discharged to the waste disposal systems. In the reactor power plant waste disposal systems the water undergoes several treatment processes before being released to the environment, but none of these processes is effective in removing tritium. Tritium may compose between 50 and almost 100 percent of the total amount of radioactive material discharged as liquid waste from nuclear reactors. The amount of tritium discharged from reactors in a gaseous form is only about 1 percent of the total tritium discharge.

Physical and Chemical Properties

The physical and chemical properties of tritium are included in the attached worksheet. It is found as a colorless gas and in the form of tritiated water. It is undetectable by conventional methods of gross radioactivity analysis. Special analytical techniques such as liquid scintillation counting must be used to measure tritium.

2. RADIATION HAZARD

Tritium is a moderately hazardous radioactive material. Because it is an isotope of hydrogen, it can be metabolized in the form of tritiated water and incorporated into body fluids and tissues.

The effects of radiation exposure are primarily dependent on the amount of radiation and the portion of the body affected. The effects of acute whole-body radiation are: (1) 0 to 25 rem, no detectable clinical effects; (2) 25 to 200 rem, delayed effects and possible shortened life expectancy of 1 percent; (3) 200 to 600 rem, possible premature death; (4) greater than 600 rem, death. These effects are for a single large dose of radiation or a series of substantial doses in a short interval of time to the total body. A single ingestion of tritiated water having an activity of 1 microcurie will produce a total dose to the body tissues of 0.21 mrem. Continuous ingestion of water having a specific activity of 1 microcurie of tritium per milliliter will produce a dose rate of 170 rem per year to body tissues.

Standards for prolonged exposure over a fifty-year period have defined the single dose limit in terms of the maximum permissible dose accumulated in a period of 13 weeks. The whole body exposure limit is 3 rem per quarter and the accumulated dose limit is 5(N-18), where N is the individual's age in years.

3. OTHER HAZARDS

Besides its radiation hazard tritium is slightly toxic.[0766]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, Transportation

Since tritium is moderately hazardous to man by inhalation or ingestion, care must be exercised in its handling. Handling must be set up to prevent excessive exposure to personnel and, in fact, to prevent any unnecessary exposure.

These materials should be stored in controlled reservations in specially constructed containers or storage bins. Tritium, as a gas, as luminous paint, or adsorbed on solid material is classified as a group VII radionuclide by the Department of Transportation. The rules and regulations governing its transportation are given in the Code of Federal Regulations (CFR) Title 49--Transportation, Parts 170 to 190.[2150] The transport group VII radionuclide content is limited to 1,000 curies for a Type A package and 50,000 curies for a Type B package defined in 49CFR173. Their release rate is limited to zero under the specified accident conditions for Type A and B quantities.[2150]

Disposal/Reuse

The disposal of these materials is governed by the AEC Manual Chapter 0524 [0559] and 10CFR20.[2149] Two sets of standards have been established for the permissible radiation exposure in unrestricted areas. One is for the greatest dose received by an individual and the other for the average dose received by the general population. The standards for the safe release of this material to the environment in an unrestricted area are contained in 10CFR20 [2149] and its release should not exceed the concentrations in air and water listed in this report (Table 2). These release rates apply to an individual and its release may be limited if a suitable sample of the population is exposed to one-third the concentrations in air or water specified in this report (Table 2).

The disposal by release in a sanitary sewage system is limited to 10,000 microcuries.[2149] The disposal by burial at any one location and time is limited to 100 times the above amount.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Recovery

Tritium is not currently recovered at the reactor site or the fuel reprocessing plant site. However, the Oak Ridge National Laboratory is conducting experimental work on recovering tritium during fuel reprocessing for the fast breeder reactor. ~~B~~vol oxidation is the term for the tritium recovery process being investigated in which the fuel, after being chopped in the head-end process, is heated to drive off the tritiated hydrogen. By collecting and condensing the effluent, greater than 99 percent of the tritium is recovered. It is feasible that such a process could be incorporated into the reprocessing of fuel from the present, light water reactors.

Disposal

The current method of tritium disposal is dilution and dispersion, both at the reactor site and the fuel reprocessing plant site. Most of this release is in the form of tritiated water in the liquid waste streams and only a very small percent is released to the air. Tritium discharge concentrations are usually much less than 1 percent of the discharge limits. Because of the inherently small radiological hazard from tritium, the difficulty of removing tritium from the reactor's tritiated water, and the small percentage of the allowable concentrations that are currently being released to the environment at the reactor site, tritium removal is probably not practical in the near future. At the fuel reprocessing plant, however, a process similar to the ~~b~~vol oxidation process should be incorporated in order to recover tritium and dispose of it by one of the following methods.

Option No. 1 - Land Burial. Land burial of tritium wastes, in small concentrations, at approved sites that are acceptable from a geologic and hydrologic standpoint, is an acceptable means of disposal. Its concentrations should not be in excess of 10^4 times its maximum permissible concentrations for the general population in 10CFR20.[2149] The burial trenches should be designed not to intercept the ground water table and constructed with a bottom drain and sump for water monitoring. The trenches should be covered with either asphalt or vegetation to prevent infiltration of water. The burial site design, geology, and hydrology should be in conformance with the criteria used in selecting and licensing the present commercial burial sites.[1423] Since land burial has successfully been practiced on a commercial scale, it should be considered as the most satisfactory method of disposing of low concentrations of these wastes.

Option No. 2 - Near Surface Storage. The disposal of high concentrations of these wastes in engineered surface facilities offers the best immediate method for disposal of these wastes. The technology for these facilities has been developed and the wastes will be under surveillance and control and can be retrieved, should this be required. The wastes will be stored in steel vaults encased in concrete. The vaults will be either air or water cooled. The periodic replacement of the waste containers may be required.

Option No. 3 - Salt Deposits. This method offers the greatest potential for the disposal of this radionuclide. This method of disposal has been under study by the Oak Ridge National Laboratory since 1957, and in November 1970 a committee of the National Academy of Sciences recommended that the use of bedded salt for the disposal of radioactive wastes is satisfactory.[0733] The wastes are buried in rooms carved in the salt deposits approximately 1,000 ft below the ground. The salt is a good heat transmitter, provides about the same radioactive shielding as concrete, and can heal its own fractures by plastic flow. The critical problem is the selection of a site that meets the necessary design and geological criteria. Salt deposits should be considered for the disposal of these wastes at approved sites that are acceptable from a design and geological standpoint. In addition, a method of waste retrieval is required in the event the integrity of the site is destroyed.

To summarize, the majority of the tritium generated by the nuclear power reactors is released to the environment in the form of liquid wastes. Most of this release occurs at the fuel reprocessing plant, where the tritium could be recovered by ~~b~~vol oxidation or a similar process. The tritium should be encapsulated and disposed of in salt deposits or near-surface engineered facilities.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Tritium is a candidate for a National Disposal Site due to its projected growth with that of the civilian nuclear power program. It should be recovered and encapsulated at the fuel reprocessing plant and shipped to the National Disposal Site. The recommended process for the disposal of this waste is:

Process	Order of Preference	Remarks
Near-surface solid storage	First Choice	Demonstrated technology; waste under constant surveillance and control and can be retrieved.
Salt beds	Second Choice	Affords permanent disposal without constant surveillance; further development required for a waste retrievel plan and location of an acceptable site.

7. REFERENCES

0559. AEC Manual, Chapter 0524. Standards for radiation protection May 12, 1964. 11 p.

0705. Staff of the Oak Ridge National Laboratory. Siting of fuel reprocessing plants and waste management facilities. ORNL-4451, 1970. 500 p.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed., New York, Reinhold Publishing Corp., 1968. 1,251 p.

2148. Atomic Energy Commission. Forecase of growth of nuclear power, Jan. 1971. Washington, U. S. Government Printing Office, WASH-1139, 1971. 187 p.

2149. Code of Federal Regulations. Title 10--atomic energy. (Revised as of Jan. 1, 1971). Washington, U. S. Government Printing Office, 1971. 429 p.

2150. Code of Federal Regulations. Title 49--transportation, parts 1 to 199. (Revised as of Jan. 1, 1971). Washington, U. S. Government Printing Office, 1971. 952 p.

2378. Selected materials on environmental effects of producing electric power. Report of the Joint Committee on Atomic Energy Congress of the United States. 91st Cong., 1st sess., Aug. 1969. Washington, U. S. Government Printing Office. 553 p.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

Name Tritium

Half-life 12.26 years

Type of Decay Negative Beta

Structural Formula

$_1H^3$

Molecular Wt. 6.05 Melting Pt. _____ Boiling Pt. _____

Density _____ Specific Power _____

Specific Activity 9700 curies/gm

Solubility

Cold Water _____ Hot Water _____

Others: _____

Decay Chain

$$\underset{(12.26y)}{H^3} \longrightarrow \underset{(stable)}{He^3}$$

Radiation Energy Level & Intensities

Beta: 5.6 Kev (average)
18.6 Kev (maximum)

Shipping Regulations Classified as a transport group VII radionuclide by the Department of Transportation

Comments _____

References: (1) 0766
(2) 2150
(3) 2378

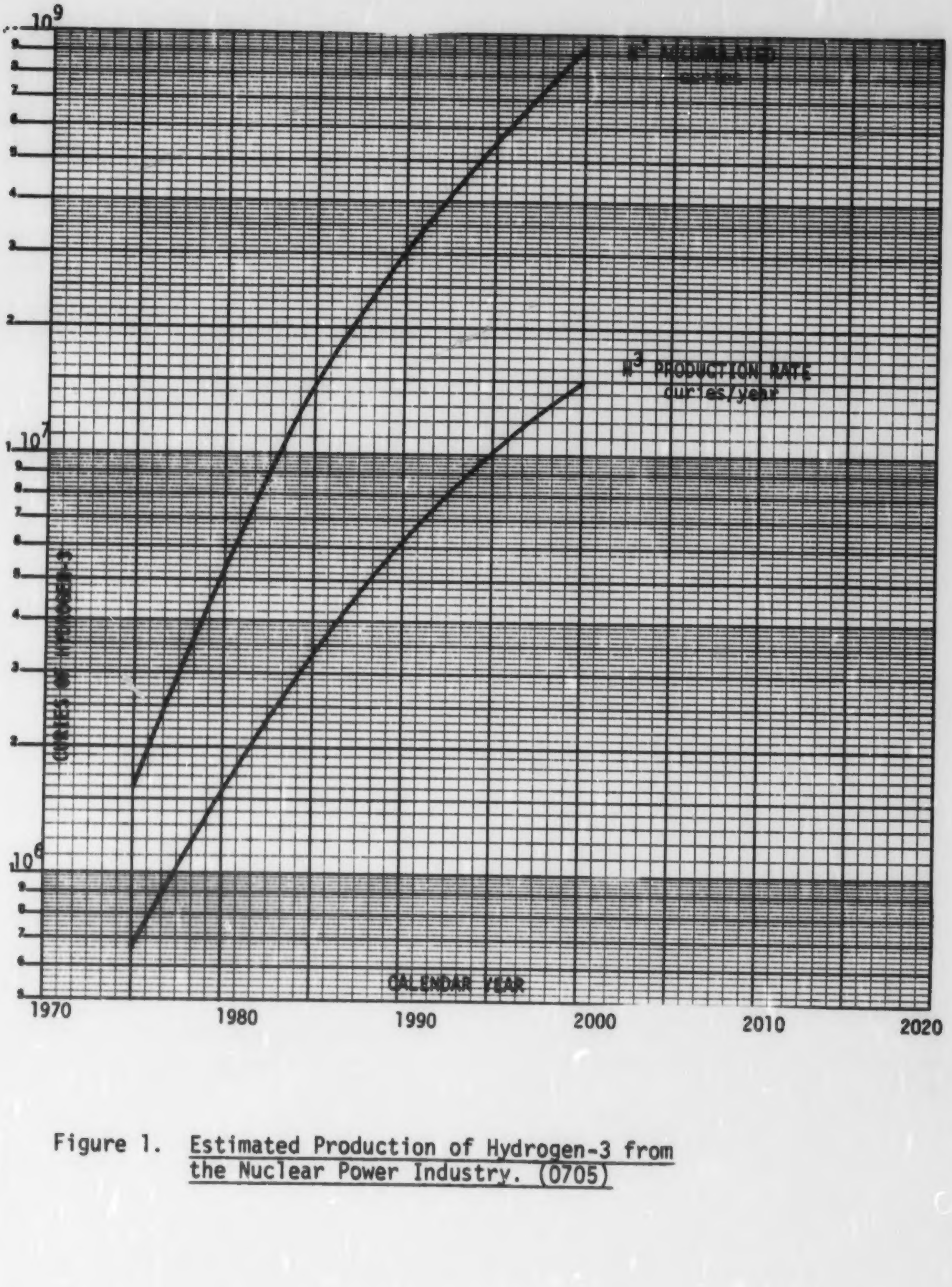

Figure 1. Estimated Production of Hydrogen-3 from the Nuclear Power Industry. (0705)

TABLE 1

ANNUAL PRODUCTION OF HYDROGEN-3 FROM THE CIVILIAN NUCLEAR POWER PROGRAM [705]

Light-Water Reactor Fuels

Annual Production	Calendar Year 1970	1980	1985	1990	2000	2020
grams/year	3.74	213	384	434	344	1010
curies/year	$.036\text{x}10^6$	$2.06\text{x}10^6$	$3.72\text{x}10^6$	$4.21\text{x}10^6$	$3.34\text{x}10^6$	$9.80\text{x}10^6$
watts/year	1.29	73.4	132	149	119	348

Fast-Breeder Reactor Fuels

Annual Production	Calendar Year 1970	1980	1985	1990	2000	2020
grams/year			34.2	207	881	2650
curies/year			$.33\text{x}10^6$	$2.01\text{x}10^6$	$8.55\text{x}10^6$	$26.8\text{x}10^6$
watts/year			11.8	71.1	304	914

TABLE 2

TRITIUM ENVIRONMENT RELEASE RATES [2149]

Fission Product	Form	Concentration in Air (microcuries/milliliter)	Concentration in Water (microcuries/milliliter)
Hydrogen-3	Soluble	$2x10^{-7}$	$3x10^{-3}$
	Insoluble	$2x10^{-7}$	$3x10^{-3}$
	Submersion*	$4x10^{-5}$	---

*Submersion means that the values given are for submersion in a semispherical infinite cloud of airborne material.

APPENDIX B - PROFILE REPORT SUMMARY

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HAZARDOUS WASTE

*[illegible]

PART. NO.	H.W. MATERIAL	[illegible]	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED * TREATMENT
8	Acrolein (28,29)	YES	3	3 (p. 43)	CONCENTRATED: RETURN TO SUPPLIER (RECYCLE) OR INCINERATION. DILUTE: OXIDATION
13	Aldrin (28,29)	YES	5	5 (p. 144)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN.), CHEMICAL OXIDATION ANAEROBIC DEGRADATION
15	Allyl Chloride (29)	NO	6	5 (p. 170)	CONCENTRATED: INCINERATION WITH HCL REMOVAL DILUTE: (ORGANIC) INCINERATION. (AQUEOUS) INCINERATION WITH HCL REMOVAL
16	Aluminum Fluoride (28)	NO	5	9 (p. 13)	RECOVERY/RECYCLE WHERE ECONOMICALLY FEASIBLE.
21	Ammonium Chromate	YES	4	4 (p. 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
22	Ammonium Dichromate (28)	YES	4	4 (p. 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
25	Ammonium Fluoride (28)	NO	5	6 (p. 35)	LIME SLURRY, LAGOONING, RECOVERY OR LANDFILL. (LARGE QTYS) SLAKED LIME, NEUTRALIZATION & LANDFILL (PACKAGE LOTS & SPILLS)
33	Antimony (28)	NO	5	5 (p. 177)	RECYCLED AND/OR NOT CONSIDERED HAZARDOUS
34	Antimony, Powdered (28)	NO	5	5 (p. 177)	RECYCLED AND/OR NOT CONSIDERED HAZARDOUS
36	Antimony Pentafluoride (28)	YES	5	6 (p. 47)	RETURN TO SUPPLIER (RECYCLE); OR PRECIPITATION W/HYDROGEN SULFIDE
43	Antimony Trifluoride (28)	YES	5	6 (p. 47)	RETURN TO SUPPLIER (RECYCLE); OR PRECIPITATION W/HYDROGEN SULFIDE
45	Antimony Trioxide	NO	—	5 (p. 177)	RECYCLED AND/OR NOT CONSIDERED HAZARDOUS
46	Arsenic (28, 31, DOD)	NO	4	4 (p. 41)	RETURN TO SUPPLIER (RECYCLE); OR DOES NOT OCCUR AS A WASTE PRODUCT
50	Arsenic Trichloride (28)	YES	5	5 (p. 188)	RETURN TO SUPPLIER (RECYCLE/REPROCESS); LONG TERM STORAGE. LANDFILL IS ADEQUATE BUT NOT RECOMMENDED
51	Arsenic Trioxide (28)	YES	5	5 (p. 195)	RECYCLING/REPROCESSING BY AMERICAN SMELTING & REFINING CO.; LONG TERM STORAGE (NATIONAL DISPOSAL SITE); LANDFILL IS APPARENTLY ADEQUATE BUT NOT RECOMMENDED UNLESS LARGE OVERSTOCKS OF As_2O_3 ARE PRESENT.
52	Barium Carbonate (28)	NO	5	6 (p. 57)	PRECIPITATION WITH SULFATE ION. (ADEQUATELY HANDLED AT INDUSTRIAL SITE LEVEL)
53	Barium Chloride (28)	NO	5	6 (p. 57)	PRECIPITATION WITH SULFATE ION. (ADEQUATELY HANDLED AT INDUSTRIAL SITE LEVEL)
55	Benzene Hexachloride (Lindane)	YES	5	5 (p. 206)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN.) COAGULATION & FILTRATION [illegible] ALKALINE HYDROLYSIS AND ANAEROBIC DEGRADATION
58	Benzyl Chloride (28)	NO	6	6 (p. 75)	CONCENTRATED: INCINERATION W/SCRUBBER (HYDROGEN CHLORIDE REMOVAL) DILUTE AQUEOUS: [illegible]; OR RETENTION PLUS BURIAL DILUTE ORGANIC: INCINERATION W/SCRUBBER; OR RETENTION PLUS BURIAL
59	Beryllium Powder (28)	NO	5	5 (p. 236)	RECOVERY/RECYCLE OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE.
60	Boric Acid	NO	9	9 (p. 79)	COAGULATION W/LIME/FILTRATION & ION EXCHANGE
61	Boron Hydrides (28, DOD)	YES	6	6 (p. 85)	INCINERATION W/SCRUBBER; OR HYDROLYSIS
63	Boron Trifluoride (28)	NO	3	3 (p. 51)	RECYCLED, OR WATER SPRAY/LIME TREATMENT; LANDFILL, LAGOONED
64	Bromic Acid (28)	NO	7	9 (p. 87)	REDUCTION/RECOVERY OF SODIUM BROMIDE
65	Bromine (28)	NO	5	4 (p. 45)	RECOVERY PRACTICED BY SUPPLIER FOR REUSE OR SALE [illegible] & IS ADEQUATE.
66	Bromine Pentafluoride	YES	3	3 (p. 50)	CHARCOAL PACKED REACTOR; OR DILUTION CONVERSION TO CHLORINE/BROMINE
77	Butyl Mercaptan (28,29)	NO	5	5 (p. 246)	CONCENTRATED: (GAS) FLARE BURNING OR ACTIVATED CARBON SCRUBBER (LIQUID) INCINERATION W/SCRUBBER; OR RECYCLE DILUTE: INCINERATION W/SCRUBBERS

PART NO.	H.W MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
80	CACODYLIC ACID	NO	6	8 (p. 11)	LONG TERM STORAGE; RECYCLE/REUSE (RETURNED TO SUPPLIERS FOR RESALE); LANDFILL (ONLY IF STORED STOCKS BECOME TOO LARGE)
81	CADMIUM (34, DOD)	YES	7	7 (p. 67)	ACTIVATED-CARBON BED; COAGULATION & FILTRATION; ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
82	CADMIUM, POWDERED (28)	YES	7	7 (p. 67)	ACTIVATED-CARBON BED; COAGULATION & FILTRATION; ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
83	CADMIUM CHLORIDE (347)	YES	7	7 (p. 67)	ACTIVATED-CARBON BED; COAGULATION & FILTRATION; ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
84	CADMIUM CYANIDES (347)	YES	5	5 (p. 258)	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE). (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
85	CADMIUM OXIDE FUME (28)	YES	7	7 (p. 67)	ACTIVATED-CARBON BED; COAGULATION & FILTRATION; ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
86	CADMIUM PHOSPHATE (33, 34)	YES	7	7 (p. 67)	ACTIVATED-CARBON BED; COAGULATION & FILTRATION; ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
87	CALCIUM ARSENATE (28)	YES	5	5 (p. 285)	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
88	CALCIUM ARSENITE (28, DOD)	YES	6	6 (p. 111)	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
91	CALCIUM CYANIDE	YES	—	5 (p. 258)	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
101	CARBONYL CHLORIDE (PHOSGENE) (28)	YES	4	4 (p. 51)	REACTION WITH STEAM/Na_2CO_3 SCRUBBING; CAUSTIC SCRUBBING; REACTION WITH ALCOHOL
105	CHLORINE (26)	YES	5	5 (p. 306)	RECOVERY/REUSE; ALKALINE SCRUBBING; WATER SCRUBBING; CARBON TETRACHLORIDE SCRUBBING
106	CHLORINE TRIFLUORIDE & CHLORINE PENTAFLUORIDE ([illegible])	YES	3	3 (p. 66)	PROPANE BURNER; WATER SPRAY; REACTION W/SODIUM CHLORIDE; (INDUSTRIAL SITE) REACTION W/CHARCOAL BED AT NATIONAL DISPOSAL SITE
107	CHLOROACETOPHENONE	YES	6	7 (p. 93)	INCINERATION (WHEN PACKAGED W/EASILY COMBUSTIBLE MATERIALS); REACTION W/SODIUM SULFIDE
111	CHLOROPICRIN (28)	NO	5	6 (p. 131)	CONCENTRATED: RECYCLE (TO SUPPLIERS) OR INCINERATION W/SCRUBBER DILUTE: LANDFILL (IF REACTED W/SODIUM SULFITE OR SODIUM BISULFITE + SLUDGE INCINERATED) [illegible]: INCINERATION W/SCRUBBER
112	CHLOROSULFONIC ACID (DOD)	NO	6	7 (p. 99)	NEUTRALIZED & DISCHARGED INTO STREAM OR STORM SEWER.
113	CHROME (22)	NO	6	6 (p. 137)	RECYCLE FOR USE IN NEW PRODUCTS. NOT CONSIDERED A HAZARD.
114	CHROMIC ACID (LIQUID, CHROMIUM TRIOXIDE) (347, 28)	YES	6	6 (p. 143)	RECYCLE OR REDUCTION/PRECIPITATION
119	COPPER ARSENATES (28)	YES	5	5 (p. [illegible])	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
120	COPPER CYANIDES (347, 29)	YES	5	5 (p. 25[illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE). (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
121	COPPER NITRATE (22, 27, 347)	NO	9	9 (p. 137)	RECOVERY; PRECIPITATION/LANDFILL
129	CYANIDES (2834, 29)	YES	5	5 (p. 25[illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE). (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
135	2,4-D (2,4-DICHLOROPHENOXYACETIC ACID) (29)	YES	6	6 (p. 1[illegible])	CONCENTRATED: INCINERATION W/CHLORINE RECOVERY; SOIL SURFACE APPLICATION DILUTE: ACTIVATED-CARBON BED (GRAN.); ACTIVATED CARBON (POWDERED); BIOLOGICAL DEGRADATION; ION EXCHANGE
136	DDD (28)	YES	5	5 (p. 2[illegible])	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN.) COAGULATION & FILTRATION FOR DDT or DDD, ALKALINE HYDROLYSIS & ANAEROBIC DEGRADATION
137	DDT (28, 29)	YES	5	5 (p. 2[illegible])	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN.) COAGULATION & FILTRATION FOR DDT or DDD, ALKALINE HYDROLYSIS & ANAEROBIC DEGRADATION
149	DIELDRIN (28, 29)	YES	5	5 (p. [illegible])	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN.)

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MATL. NO.	H.W. MATERIAL	NATIONAL CANDIDATE	SCHEDULED Completion Date	ACTUAL Completion Date	RECOMMENDED TREATMENT
160	DIMETHYL SULFATE (METHYL SULFATE)	YES	5	4 (p. 58)	INCINERATION, DILUTION, NEUTRALIZATION; OR WASTE WATER TREATMENT (ONLY FOR VERY DILUTE STREAMS)
162	DINITRO CRESOLS (28)	YES	6	6 (p.171)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN)
163	DINITROBENZOL (DINITROBENZENE)(28)	NO	4	4 (p.68)	CONCENTRATED: INCINERATION W/SCRUBBER DILUTE: (AQUEOUS) CONCENTRATE & TREAT SAME AS ABOVE.
164	DINITROPHENOL (28)	NO	4	4 (p. 72)	CONCENTRATED: RETURN TO SUPPLIER (RECYCLE) OR INCINERATION DILUTE: (AQUEOUS) CONCENTRATE & TREAT SAME AS ABOVE.
165	DINITROTOLUENE (DINITROTOLUOL)(28)	YES	5	5 (p. [illegible])	INCINERATION W/SCRUBBER
167	DIPHENYLAMINE (PHENYLANILINE)(28)	NO	5	5 (p. [illegible])	CONCENTRATED: INCINERATION W/SCRUBBER; LANDFILL DILUTE: LANDFILL
170	ENDRIN (28, 29)	YES	5	5 (p. [illegible])	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN), ANAEROBIC DEGRADATION
182	ETHYLENE BROMIDE (182)	YES	6	6 (p. 185)	REMOVAL FROM AIR: REFRIGERATED CONDENSATION " " WATER: STEAM STRIPPING & BLOWING WITH AIR CONCENTRATED: INCINERATION/RECOVERY (OF HALOGENS)
190	ETHYLENIMINE (28, 2	NO	5	5 (p. [illegible])	DILUTE (ORGANIC): INCINERATION W/SCRUBBER DILUTE (AQUEOUS): POLYMERIZATION/AERATION & ACTIVATED SLUDGE CONCENTRATED: INCINERATION
192	ETHYL MERCAPTAN (26, 28)	NO	5	5 (p. [illegible])	CONCENTRATED: (GAS) FLARE BURNING OR ACTIVATED CARBON [illegible] (LIQUID) INCINERATION W/SCRUBBER, OR RECYCLE DILUTE: INCINERATION W/SCRUBBER
200	FLUORINE (10, 28, DOD)	YES	3	3 (p. 75)	REACTION W/CHARCOAL BED, OR BURNING W/FUEL (GASEOUS STATE)
212	HYDRAZINE (20, 28, DOD) (ANHYDROUS DIAMINE)	NO	5	6 (p. [illegible])	CONCENTRATED: INCINERATION, OPEN PIT BURNING DILUTE: NOT CONSIDERED A HAZARD
213	HYDROBROMIC ACID	NO	—	5 (p. [illegible])	RECOVERY & CONVERSION TO BROMINE BY CHLORINATION
220	HYDROQUINONE (20, 28, 29, 34)	NO	5	5 (p. [illegible])	WASTE WATER TREATMENT OR INCINERATION
221	HYDROGEN SULFIDE	YES	—	2 (p. 88)	CLAUS-BEAVON PROCESS OR TRW S-100 PROCESS
233	LEAD (DOD)	NO	6	7 (p. [illegible])	RECLAMATION: MELTING INTO INGOTS (IF SCRAP IS PURE OR NEARLY PURE) RECOVERY IN LEAD BLAST FURNACE; RECOVERY FROM BLAST FURNACE [illegible]
234	LEAD ACETATE (22, 28)	NO	7	8 (p. 51)	DILUTE: CARBONATE OR SULFIDE PRECIPITATION CONCENTRATED: RECYCLE; CONVERSION TO SULFIDE; LANDFILL (INSOLUBLE COMPOUNDS ONLY)
235	LEAD ARSENATE (28)	YES	5	5 (p. [illegible])	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
236	LEAD ARSENITE (28)	YES	6	6 (p. 111)	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
237	LEAD CARBONATE (28)	NO	7	8 (p. 51)	DILUTE: CARBONATE OR SULFIDE PRECIPITATION CONCENTRATED: RECYCLE; CONVERSION TO SULFIDE; LANDFILL (INSOLUBLE COMPOUNDS ONLY)
238	LEAD CHLORITE (28)	NO	7	8 (p. 51)	DILUTE: CARBONATE OR SULFIDE PRECIPITATION CONCENTRATED: RECYCLE; CONVERSION TO SULFIDE; LANDFILL (INSOLUBLE COMPOUNDS ONLY)
239	LEAD CYANIDE (397)	YES	5	5 (p. [illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE), (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)

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PARA. NO.	H.W. MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
240	LEAD NITRATE (22,28,91,DOD)	NO	7	8 (p.51)	DILUTE: CARBONATE OR SULFIDE PRECIPITATION CONCENTRATED: RECYCLE; CONVERSION TO SULFIDE; LANDFILL (INSOLUBLE COMPOUNDS ONLY)
241	LEAD NITRITE	NO	7	8 (p.51)	DILUTE: CARBONATE OR SULFIDE PRECIPITATION CONCENTRATED: RECYCLE; CONVERSION TO SULFIDE; LANDFILL (INSOLUBLE COMPOUNDS ONLY)
242	LEAD OXIDE (28,29,31)	NO	7	9 (p.151)	LANDFILL; CONVERSION TO SULFIDE; CONVERSION TO CARBONATE
243	LEWISITE	YES	7	9 (p.163)	(ARMY TRANSPORTABLE DISPOSAL SYSTEM) INCINERATION W/TREATMENT OF ARSENIC BY-PRODUCTS
245	MAGNESIUM ARSENITE (DOD)	YES	7	9 (p.169)	LONG TERM PROTECTIVE STORAGE
249	MALEIC ANHYDRIDE (20,28)	NO	3	3 (p.89)	CONCENTRATED: RECYCLE; OR INCINERATION DILUTE: INCINERATION (TAR BYPRODUCTS) NEUTRALIZATION/MUNICIPAL SEWERS (MALEIC ACID)
252	MANGANESE SULFATE (20,28)	NO	7	8 (p.67)	(NON TOXIC) INSOLUBLE RESIDUES: LANDFILL; LAGOONING CONVERSION TO MANGANESE SULFATE FOR USE AS FERTILIZER
253	MERCURIC CHLORIDE (28,29,31,32)	YES	6	7 (p.118)	RECOVERY/REMOVAL FROM GASES — UNION CARBIDE PURASIV HG SYSTEM (ADSORPTION W/MOLECULAR SIEVES); SODIUM HYPOCHLORITE SCRUBBING RECOVERY/REMOVAL FROM LIQUIDS — AKTIEBOLAGET BILLINGSFORS-LANGED PROCESS; VENTRON SODIUM BOROHYDRIDE PROCESS
254	MERCURIC CYANIDE (28)	YES	5	6 (p.221)	ALKALINE CHLORINATION/SODIUM BOROHYDRIDE REDUCTION; OR CHLORINATION/ION EXCHANGE
255	MERCURIC NITRATE (28)	YES	6	7 (p.113)	RECOVERY/REMOVAL FROM GASES — UNION CARBIDE PURASIV HG SYSTEM (ADSORPTION W/MOLECULAR SIEVES); SODIUM HYPOCHLORITE SCRUBBING RECOVERY/REMOVAL FROM LIQUIDS — AKTIEBOLAGET BILLINGSFORS-LANGED PROCESS; VENTRON SODIUM BOROHYDRIDE PROCESS
256	MERCURIC SULFATE (28,10,36)	YES	6	7 (p.118)	RECOVERY/REMOVAL FROM GASES — UNION CARBIDE PURASIV HG SYSTEM (ADSORPTION W/MOLECULAR SIEVES); SODIUM HYPOCHLORITE SCRUBBING RECOVERY/REMOVAL FROM LIQUIDS — AKTIEBOLAGET BILLINGSFORS-LANGED PROCESS; VENTRON SODIUM BOROHYDRIDE PROCESS
257	MERCURY (22,26, DOD)	YES	6	7 (p.118)	RECOVERY/REMOVAL FROM GASES — UNION CARBIDE PURASIV HG SYSTEM (ADSORPTION W/MOLECULAR SIEVES); SODIUM HYPOCHLORITE SCRUBBING RECOVERY/REMOVAL FROM LIQUIDS — AKTIEBOLAGET BILLINGSFORS-LANGED PROCESS; VENTRON SODIUM BOROHYDRIDE PROCESS
258	MERCURY COMPOUNDS (ORGANIC) (28)	YES	6	8 (p.75)	DILUTE: (AQUEOUS) REDUCTION W/SODIUM BOROHYDRIDE & RECOVERY OF METALLIC MERCURY CONCENTRATE ORGANIC: INCINERATION W/MERCURY VAPOR SCRUBBER
267	METHYL BROMIDE	YES	6	6 (p.[illegible])	REMOVAL FROM AIR: REFRIGERATED CONDENSATION " " WATER: STEAM STRIPPING & BLOWING WITH AIR CONCENTRATED: INCINERATION/RECOVERY (OF HALOGENS)
268	METHYL CHLORIDE	YES	6	6 (p.185)	REMOVAL FROM AIR: REFRIGERATED CONDENSATION " " WATER: STEAM STRIPPING & BLOWING WITH AIR CONCENTRATED: INCINERATION/RECOVERY (OF HALOGENS)
272	METHYL MERCAPTAN (METHANETHIOL) (26)	NO	5	5 (p.[illegible])	CONCENTRATED: (GAS) FLARE BURNING; OR ACTIVATED CARBON SCRUBBER (LIQUID) INCINERATION W/SCRUBBER; OR RECYCLE DILUTE: INCINERATION W/SCRUBBER
274	METHYL PARATHION	YES	4	4 (p.82)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED-CARBON BED; ACTIVATED SLUDGE; ALKALINE HYDROLYSIS
287	NERVE GAS (GB,DOD) (NON PERSISTENT)	YES	5	5 (p.[illegible])	INCINERATION (TRANSPORTABLE DISPOSAL SYSTEM) OR ALKALINE HYDROLYSIS.
288	NERVE GAS (VX) (PERSISTENT) (DOD)	YES	5	5 (p.[illegible])	INCINERATION (TRANSPORTABLE DISPOSAL SYSTEM)
289	NICKEL (DOD)		5		WILL BE DONE AS CATEGORY II.
290	NICKEL AMMONIUM SULFATE (347)	NO	7	7 (p.148)	RECYCLE/REUSE; PRECIPITATION/CLARIFICATION/LANDFILL OR SEWERS; DIRECT DISCHARGE TO MUNICIPAL SEWERS (IF AT A CONTROLLED RATE & SEWAGE TREATMENT PLANT CAN EFFECTIVELY COMPLY WITH PURITY SPECIFICATIONS)
291	NICKEL ANTIMONIDE (28)	NO	7	7 (p.185)	RETURN TO SUPPLIER; ENCAPSULATION/LANDFILL

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MAT'L NO.	H.W. MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
292	NICKEL ARSENIDE (28)	NO	7	7 (p 185)	RETURN TO SUPPLIER, ENCAPSULATION/LANDFILL
293	NICKEL CARBONYL (28)	YES	5	5 (p [illegible])	LARGE QUANTITIES: RECYCLE SMALL QUANTITIES: THERMAL DECOMPOSITION & WET SCRUBBING
294	NICKEL CHLORIDE (347)	NO	7	7 (p [illegible])	RECYCLE/REUSE, PRECIPITATION/CLARIFICATION/LANDFILL OR SEWERS; DIRECT DISCHARGE TO MUNICIPAL SEWERS (IF AT A CONTROLLED RATE & SEWAGE TREATMENT PLANT CAN EFFECTIVELY COMPLY WITH PURITY REGULATIONS)
295	NICKEL CYANIDE (347)	YES	5	5 (p 258)	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
296	NICKEL NITRATE (347)	NO	7	7 (p 169)	RECYCLE/REUSE, PRECIPITATION/CLARIFICATION/LANDFILL OR SEWERS; DIRECT DISCHARGE TO MUNICIPAL SEWERS (IF AT A CONTROLLED RATE & SEWAGE TREATMENT PLANT CAN EFFECTIVELY COMPLY WITH PURITY REGULATIONS)
297	NICKEL SELENIDE (28)	NO	7	7 (p 185)	RETURN TO SUPPLIER; ENCAPSULATION/LANDFILL
298	NICKEL SULFATE (22, 28, 347)	NO	7	7 (p 169)	RECYCLE/REUSE, PRECIPITATION/CLARIFICATION/LANDFILL OR SEWERS; DIRECT DISCHARGE TO MUNICIPAL SEWERS (IF AT A CONTROLLED RATE & SEWAGE TREATMENT PLANT CAN EFFECTIVELY COMPLY WITH PURITY REGULATIONS)
300	NITROANILINE (META-, PARA-NITROANILINE) (22)	NO	5	4 (p 110)	CONCENTRATED: INCINERATION W/SCRUBBER (IF PURIFICATION/RECYCLING IS IMPRACTICAL) DILUTE (AQUEOUS) CONCENTRATE & TREAT AS ABOVE. ACTIVATED SLUDGE TREATMENT ADEQUACY IS DOUBTFUL (WASTES PRIMARILY APPEAR AS AQUEOUS)
301	NITROBENZENE (NITROBENZOL) (28)	NO	4	4 (p 118)	CONCENTRATED: RECYCLE; OR INCINERATION OF SMALL AMOUNTS DILUTE: ACTIVATED SLUDGE
302	NITROCHLOROBENZENE (META-, OR PARA-) (22, 28)	NO	6	6 (p 250)	CONCENTRATED: INCINERATION W/SCRUBBERS, LANDFILL DILUTE ORGANIC " " " DILUTE AQUEOUS: INCINERATION
306	NITROGEN MUSTARD (HN) (DOD)	YES	5	6 (p 295)	INCINERATION (TRANSPORTABLE DISPOSAL SYSTEM), CHEMICAL REACTION WITH HYPOCHLORITE FOR SMALLER QTIES.
307	NITROGLYCERIN (DOD)	YES (IN SMALL QTIES [illegible])	5	5 (p 372)	CONTROLLED INCINERATION W/SCRUBBER (OF SAFE LOT SIZES); ALKALI SULFIDES (FOR MINUTE QUANTITIES) - SUCH AS CLEANING EQUIPMENT
317	OXALIC ACID (28)	NO	4	4 (p 125)	NEUTRALIZATION (LIMESTONE)/INCINERATION/RECYCLE (INCINERATORS EQUIPPED WITH PARTICULATE REMOVAL DEVICES)
321	PARATHION (29)	YES	4	4 (p 89)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED-CARBON BED; ACTIVATED SLUDGE; ALKALINE HYDROLYSIS
322	PENTACHLOROPHENOL (28)	YES	6	9 (p 173)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED-CARBON BED, ION EXCHANGE, BIOLOGICAL DEGRADATION
324	PERCHLORIC ACID (TO 72% STRENGTH) (22, DOD)	YES	7	9 (p 183)	CHEMICAL REDUCTION
326	PERCHLORYL FLUORIDE (28, 2892)	YES	7	7 (p 195)	REACTION W/CHARCOAL BED
332	PHOSPHORUS WHITE OR YELLOW (WP) (DOD)	NO	5	9 (p 189)	SMALL QUANTITIES: MUNICIPAL INCINERATION LARGE QUANTITIES: RECOVERY AT PHOSPHORUS PLANTS
333	PHOSPHORUS OXYCHLORIDE (28, 29)	NO	7	8 (p 97)	DECOMPOSITION; NEUTRALIZATION; RECYCLE (ALL THREE ARE EQUALLY EFFECTIVE)
334	PHOSPHORUS PENTACHLORIDE (28)	NO	7	8 (p 97)	DECOMPOSITION; NEUTRALIZATION; RECYCLE (ALL THREE ARE EQUALLY EFFECTIVE)
335	PHOSPHORUS PENTASULFIDE (28, 29)	NO	7	8 (p 89)	LARGE QUANTITIES: DECOMPOSITION W/WATER; INCINERATION SMALL QUANTITIES: DECOMPOSITION W/WATER; BURIAL
336	PHOSPHORUS TRICHLORIDE (22, 28, 29)	NO	7	8 (p 97)	DECOMPOSITION; NEUTRALIZATION; RECYCLE (ALL THREE ARE EQUALLY EFFECTIVE)

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MATL. NO.	H W MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
338	PICRIC ACID (2&X DoD) (TRINITRO-PHENOL LIQUID)	YES - (SMALL QUANTITIES)	5	8 (p 119)	DILUTE: [illegible] CHEMICAL REACTION IN DILUTE SOLUTION (PREFERRED AT INDUSTRIAL SITE) CONCENTRATED (CONTAMINATED) SAME AS DILUTE. IF NOT CONTAMINATED, RECOVERY/RECYCLE.
341	POTASSIUM ARSENITE (28)	YES	6	6 (p 111)	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
343	POTASSIUM CHROMATE (28)	YES	4	4 (p 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
344	POTASSIUM CYANIDE, SOLID (347, 28)	YES	5	5 (p [illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE). (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
345	POTASSIUM DICHROMATE (20, 22, 26, 28, 289?, 31, 34)	YES	4	4 (p 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
346	POTASSIUM FLUORIDE	NO	5	6 (p 25)	LIME SLURRY, LAGOONING, RECOVERY OR LANDFILL (LARGE QTIES) SLAKED LIME, NEUTRALIZATION & LANDFILL (PACKAGE LOTS & SPILLS)
349	POTASSIUM PERMANGANATE (DOD)	NO	6	9 (p 97)	CHEMICAL REDUCTION
350	POTASSIUM PEROXIDE (28, DOD)	NO	—	5 (p 377)	NEUTRALIZATION/DISCHARGED INTO RIVER
365	QUINONE (22)	NO	5	5 (p [illegible])	INCINERATION; ACTIVATED SLUDGE (WITH PRIOR REDUCTION TO HYDROQUINONE OR HYDROQUINONE DERIVATIVE)
367	SELENIUM, POWDERED (28, 33)	NO	5	5 (p [illegible])	RECOVERY/RECYCLE
370	SILVER CYANIDES (28, 347)	YES	5	5 (p [illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
374	SODIUM ALLOY	NO	—	2 (p 45)	PLACED IN PERFORATED DRUMS AND DUMPED AT SEA; OR BURNING W/KEROSENE IN A CLOSED CHEMICAL REACTOR; OR PACKED IN BARRELS/CONCRETE COLLARS AND DUMPED AT SEA
376	SODIUM ARSENATE (28)	YES	5	5 (p 285)	LONG TERM STORAGE, RECYCLE/REUSE, RECOVERY
377	SODIUM ARSENITE (28)	YES	6	6 (p 111)	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
378	SODIUM AZIDE (28, 289?)	NO	6	6 (p 248)	REACTION W/SULFURIC ACID & SODIUM NITRATE
379	SODIUM BICHROMATE (SODIUM DICHROMATE) (28, 31, 33, 347)	YES	6	4 (p 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
382	SODIUM CACODYLATE (28)	NO	6	8 (p 11)	LONG TERM STORAGE, RECYCLE/REUSE (RETURNED TO SUPPLIERS FOR RESALE); LANDFILL (ONLY IF STORED STOCKS BECOME TOO LARGE)
386	SODIUM CHROMATE (22, 28, 31)	YES	4	4 (p 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
387	SODIUM CYANIDE (28, 347)	YES	5	5 (p [illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
389	SODIUM FLUORIDE (28, 33, 347)	NO	5	6 (p 25)	LIME SLURRY, LAGOONING, RECOVERY OR LANDFILL (LARGE QTIES) SLAKED LIME, NEUTRALIZATION & LANDFILL (PACKAGE LOTS & SPILLS)
400	SODIUM PEROXIDE (22, 26, 28)	NO	—	5 (p 377)	(ONLY ONE MANUFACTURER IN U.S. — PEROXIDE IS PRODUCED BY CONTROLLED OXIDATION OF SODIUM METAL WITH NO WASTES)
402	SODIUM POTASSIUM ALLOY	NO	—	2 (p 45)	PLACED IN PERFORATED DRUMS AND DUMPED AT SEA; OR BURNING W/KEROSENE IN A CLOSED CHEMICAL REACTOR; OR PACKED IN BARRELS/CONCRETE COLLARS, AND DUMPED AT SEA
410	STRONTIUM	NO	—	5 (p 399)	CONCENTRATED: PURIFICATION/RECYCLED DILUTE: MINUTE QTIES. WASHED DOWN DRAIN. H_2 GAS EVOLVED SLOWLY & IS KEPT WELL BELOW FLAMABLE LIMIT. (WAS ONLY 8000 LB WORLD ANNUAL PRODUCTION)

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PATE. NO	H.W MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
422	TEAR GAS (CN)(DOD)	YES	5	7 (p. 98)	INCINERATION (WHEN PACKAGED W/EASILY COMBUSTIBLE MATERIALS; REACTION W/SODIUM SULFIDE
423	TEAR GAS, IRRITANT (CS)(DOD)	YES	5	8 (p. 119)	HYDROLYZE WITH 95% ETHANOL, AND BURN REACTION PRODUCT IN INCINERATOR EQUIPPED WITH ALKALINE SCRUBBER
425	TETRAETHYL LEAD (ALL MIXES) (28,29)	NO	5	6 (p. 30	INCINERATION W/SCRUBBER, & RECYCLE; ION EXCHANGE; IMPROVED PRECIPITATION/REUSE (NOTE: PRESENT METHODS ARE NOT COMPLETELY ACCEPTABLE & INTENSIVE STUDY HAS BEEN MADE CONCLUDING WITH THE ABOVE [illegible])
427	TETRAMETHYL LEAD (29)	NO	5	6 (p. 2	SAME AS TETRAETHYL LEAD (425)
428	TETRANITROMETHANE (DOD)	NO	3	3 (p. 91)	RETURN TO SUPPLIER/RECYCLE; ENCLOSED PIT BURNING W/BLOWERS -- GASES ARE PASSED THROUGH LOOSELY PACKED EARTH OR THROUGH WET SCRUBBERS
453	ZINC ARSENATE (23)	YES	5	5 (p. 20	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
454	ZINC ARSENITE (28)	YES	6	6 (p. 111)	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
455	ZINC CHLORATE (28,33,34)		7		WILL BE DONE AS CATEGORY II
457	ZINC CYANIDE	YES	—	5 (p. 19	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
458	ZINC ETHYL (28)		7		WILL BE DONE AS CATEGORY II
459	ZINC NITRATE (28)	NO	7	9 (p. 203)	RECOVERY, DESTRUCTIVE PRECIPITATION BY PH ADJUSTMENT
461	ZINC PERMANGANATE (28)	NO	7	9 (p. 203)	RECOVERY, DESTRUCTIVE PRECIPITATION BY PH ADJUSTMENT
462	ZINC PEROXIDE (28)	NO	7	9 (p. 203)	RECOVERY, DESTRUCTIVE PRECIPITATION BY PH ADJUSTMENT
463	ZINC SULFIDE (28)	NO	7	9 (p. 203)	RECOVERY; DESTRUCTIVE PRECIPITATION BY PH ADJUSTMENT
469	BARIUM CYANIDE	NO	5	6 (p. 57)	PRECIPITATION WITH SULFATE ION (ADEQUATELY HANDLED AT INDUSTRIAL SITE LEVEL)
470	BARIUM FLUORIDE	NO	5	9 (p. 13)	RECOVERY/RECYCLE WHERE ECONOMICALLY FEASIBLE.
471	BARIUM NITRATE	NO	5	6 (p. 57)	PRECIPITATION WITH SULFATE ION (ADEQUATELY HANDLED AT INDUSTRIAL SITE LEVEL)
472	BARIUM SULFIDE	NO	5	6 (p. 57)	PRECIPITATION WITH SULFATE ION (ADEQUATELY HANDLED AT INDUSTRIAL SITE LEVEL)
473	BERYLLIUM CARBONATE	NO	5	5 (p. 23	RECOVER/RECYCLE OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE.
474	BERYLLIUM CHLORIDE	NO	5	5 (p. 23	RECOVER/RECYCLE OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE.
475	BERYLLIUM HYDROXIDE	NO	5	5 (p. 23	RECOVER/RECYCLE OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE
476	BERYLLIUM OXIDE	NO	5	5 (p. 23	RECOVER/RECYCLE OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE.

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MAT'L NO	H W MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
477	BERYLLIUM SELENATE	NO	5	5 (p 2[illegible])	RECOVERY/RECYCLE; OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE
478	CADMIUM FLUORIDE	NO	5	9 (p 13)	RECOVERY/RECYCLE WHERE ECONOMICALLY FEASIBLE.
479	CADMIUM NITRATE	YES	7	7 (p 67)	ACTIVATED-CARBON BED, COAGULATION & FILTRATION, ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
480	CADMIUM POTASSIUM CYANIDE	YES	7	7 (p 67)	ACTIVATED-CARBON BED, COAGULATION & FILTRATION, ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
481	CADMIUM SULFATE	YES	7	7 (p 67)	ACTIVATED-CARBON BED, COAGULATION & FILTRATION, ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
484	CHLORODANE	YES	5	5 (p [illegible])	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN.), ACID HYDROLYSIS, CHEMICAL OXIDATION, ANAEROBIC DEGRADATION
485	CHROMIC FLUORIDE	NO	6	7 (p 2[illegible])	PRECIPITATION; DILUTION/DISCHARGE INTO MUNICIPAL SEWERS
486	CHROMIC SULFATE	NO	6	7 (p 2[illegible])	PRECIPITATION; DILUTION/DISCHARGE INTO MUNICIPAL SEWERS
487	CHROMIC CYANIDE	NO	6	7 (p 2[illegible])	DOES NOT EXIST AS A COMPOUND
490	COPPER ACETOARSENITE	YES	6	6 (p [illegible])	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
491	DEMETON	YES	4	4 (p [illegible])	CONCENTRATED: INCINERATION DILUTE: ACTIVATED-CARBON BED, ACTIVATED SLUDGE, ALKALINE HYDROLYSIS
495	GUTHION	YES	4	4 (p [illegible])	CONCENTRATED: INCINERATION DILUTE: ACTIVATED-CARBON BED, ACTIVATED SLUDGE; ALKALINE HYDROLYSIS
496	HEPTACHOR	YES	5	5 (p [illegible])	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN.), CHEMICAL OXIDATION, ANAEROBIC DEGRADATION
499	MANGANESE	NO	6	7 (p [illegible])	LANDFILL IS ADEQUATE, & NOT CONSIDERED HAZARDOUS. HOWEVER, IMPROVED DUST CONTROL IS HIGHLY RECOMMENDED
500	MANGANESE ARSENATE	YES	5	5 (p 2[illegible])	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
501	MANGANESE CHLORIDE	NO	7	8 (p 67)	(NONTOXIC) INSOLUBLE RESIDUES: LANDFILL, LAGOONING CONVERSION TO MANGANESE SULFATE FOR USE AS FERTILIZER
502	MANGANESE METHYL-CYCLOPENTADIENYLTRI-CARBONYL	NO	7	7 (p [illegible])	OIL STORAGE - [illegible]; INCINERATION/[illegible] IF EMISSION LEVEL IS ACCEPTABLE WATER STORAGE - SETTLING POND WITH LIME ADDED
503	MERCURIC DIAMMONIUM CHLORIDE	YES	6	7 (p 1[illegible])	[illegible] — [illegible] [illegible] SODIUM HYPOCHLORITE SCRUBBING [illegible] REMOVAL FROM LIQUIDS — [illegible] PROCESS; NEUTRON SODIUM BOROHYDRIDE PROCESS
505	PENTABORANE	YES	6	6 (p [illegible])	INCINERATION W/SCRUBBER OR HYDROLYSIS
507	POLYCHLORINATED BIPHENYLS (ASKARELS)	NO	5	5 (p [illegible])	CONCENTRATED: RETURN TO SUPPLIER DILUTE (SOLID): HIGH TEMP. INCINERATION W/SCRUBBER " (LIQUID ORGANIC): RETURN TO SUPPLIER " [illegible]
508	SODIUM OXIDE	NO	–	5 (p 2[illegible])	(SAME TREATMENT AS SODIUM WASTES)
514	BENZOYL PEROXIDE	NO	7	9 (p 2[illegible])	TREAT WITH 10 X 10% SODIUM HYDROXIDE AND FLUSH BIODEGRADABLE SODIUM BENZOATE DOWN SEWER
515	1,2,4-BUTANETRIOL TRINITRATE (BTN)	NO	7	9 (p 2[illegible])	CONTROLLED INCINERATION W/SCRUBBER

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MAT'L NO.	H.W. MATERIAL	NATIONAL CAND. DATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
516	CHLORATES WITH RED PHOSPHORUS	NO	7	9 (p.22[illegible])	CONTROLLED INCINERATION w/MUNICIPAL INCINERATORS
517	COPPER ACETYLIDE	YES	7	8 (p.133)	INTERIM DISPOSAL – DETONATION AT NATIONAL DISPOSAL SITE, OR IF TOO HAZARDOUS TO TRANSPORT, IN CLEARED AREA. RESEARCH ON SATISFACTORY DISPOSAL REQUIRED.
518	COPPER CHLOROTETRAZOLE	YES – IF MFGD	7	9 (p.235)	IF SAFE, CONTROLLED INCINERATION OF SLURRY.
519	CYANURIC TRIAZIDE	NO	7	8 (p.139)	DETONATION BY TRAINED ORDNANCE PERSONNEL
520	DETONATORS	YES	7	8 (p.145)	DESTRUCTION IN SPECIAL DETONATOR DESTRUCTION FURNACE EQUIPPED WITH SCRUBBING DEVICES, IF SAFE FOR TRANSPORT.
521	DIAZODINITROPHENOL (DDNP)	YES	7	8 (p.151)	IF SAFE, CONTROLLED INCINERATION OF WATER SLURRY OF DDNP (IF IMPOSSIBLE TO HANDLE CONTAMINATED WASTE AS SLURRY, CHEMICAL DECONTAMINATION) IF UNSAFE, DETONATION IN CLEARED AREA.
522	DIPENTAERYTHRITOL-HEXANITRATE (DPEHN)	YES	7	8 (p.159)	IF SAFE, USE CONTROLLED INCINERATION IN ROTARY KILN EQUIPPED WITH SCRUBBERS. IF UNSAFE, DETONATION IN CLEARED AREA.
523	GELATINIZED NITROCELLULOSE	YES	7	8 (p.165)	CONTROLLED INCINERATION, IN SYSTEM EQUIPPED WITH AFTERBURNER AND SCRUBBERS.
524	GLYCEROLMONOLACTATE TRINITRATE (GLTN)	NO	7	9 (p.239)	CONTROLLED INCINERATION – FURTHER RESEARCH RECOMMENDED
525	GLYCOL DINITRATE (DGN)	YES – AS [illegible]	7	8 (p.171)	CONTROLLED INCINERATION w/SCRUBBER
526	GOLD FULMINATE (FULMINATING GOLD)	YES - IF MFGD	7	9 (p.233)	IF SAFE, CONTROLLED INCINERATION OF SLURRY
527	HYDRAZINE AZIDE/ HYDRAZINE	YES - IF PRODUCED COMMERCIALLY	7	9 (p.245)	EXPERIMENTAL MATERIAL CONTROLLED INCINERATION WITH SCRUBBER, AS PER HYDRAZINE
528	HYDRAZOIC ACID	NO	7	7 (p.253)	DILUTION/NEUTRALIZATION/STORM SEWERS OR STREAM (CONSIDERED TOO HAZARDOUS FOR SHIPMENT)
529	LEAD AZIDE	YES	7	8 (p.177)	DISPOSAL BY ELECTROLYSIS, IF SAFE; IF UNSAFE, DETONATION IN CLEARED AREA.
530	LEAD 2,4 DINITRORESORCINATE (LDNR)	YES	7	9 (p.251)	IF SAFE, CONTROLLED SLURRY INCINERATION IF UNSAFE, DETONATE IN CLEARED AREA.
531	LEAD STYPHNATE (LEAD TRINITRORESORCINATE)	YES	7	8 (p.187)	IF SAFE, USE CONTROLLED INCINERATION IN ROTARY KILN EQUIPPED WITH SCRUBBERS. IF UNSAFE, DETONATION IN CLEARED AREA.
532	MANNITOL HEXANITRATE	YES	7	8 (p.195)	IF SAFE, DETONATE OR BURN AT N.D.S. (UNTIL RESEARCH DEVELOPS BETTER TECHNIQUE) IF UNSAFE, DETONATE OR BURN IN NEAREST CLEARED AREA.
533	MERCURY FULMINATE (FULMINATE OF MERCURY)	NO	7	8 (p.201)	WET DECOMPOSITION BY AQUEOUS $Na_2S_2O_3$
534	NITROCELLULOSE	YES	7	9 (p.257)	IF SAFE, CONTROLLED INCINERATION. IF UNSAFE, BURN IN A CLEARED AREA.
535	POLYVINYL NITRATE (PVN)	NO	7	9 (p.262)	NOT MANUFACTURED OR USED.
536	POTASSIUM DINITROBENZOFUROXAN (KDNBF)	YES	7	8 (p.209)	DESTROYED BY CONTROLLED INCINERATION OF SLURRY IN ROTATING KILN EQUIPPED w/SCRUBBERS.

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MAT'L No	H W MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
537	SILVER ACETYLIDE	YES	7	8 (p.133)	INTERIM DISPOSAL - DETONATION AT NATIONAL DISPOSAL SITE, OR IF TOO HAZARDOUS TO TRANSPORT, IN CLEARED AREA. RESEARCH ON SATISFACTORY DISPOSAL REQUIRED.
538	SILVER AZIDE	YES	7	8 (p.213)	IF SAFE, DISPOSE OF CHEMICALLY WITH ELECTROLYSIS FOR RECOVERY OF SILVER. IF UNSAFE, DETONATION IN CLEARED AREA.
539	SILVER STYPHNATE	YES - IF NEED	7	9 (p.235)	IF SAFE, CONTROLLED INCINERATION OF SLURRY.
540	SILVER TETRAZENE	YES	7	9 (p.235)	CONTROLLED INCINERATION W/SCRUBBER
541	SMOKELESS GUN POWDER	YES	7	9 (p.269)	IF SAFE, CONTROLLED INCINERATION W/SCRUBBER IF UNSAFE, BURN IN CLEARED AREA.
542	TETRAZENE (TETRACENE; 1(5-TETRAZOLYL)-4-GUANYL TETRAZENE HYDRATE)	YES	7	8 (p.221)	IF SAFE, THERMAL DECOMPOSITION WITH STEAM. IF UNSAFE, DETONATION IN CLEARED AREA.
215	HYDROCYANIC ACID	NO	—	6 (p.213)	DILUTE: pH ADJUSTMENT/CHLORINE OR HYPOCHLORITE ADDITION/pH ADJUSTMENT/OXIDATION. CONCENTRATED: INCINERATION W/ALKALINE SCRUBBER.
218	HYDROGEN CYANIDE	NO	—	6 (p.21	DILUTE: pH ADJUSTMENT/CHLORINE OR HYPOCHLORITE ADDITION/pH ADJUSTMENT/OXIDATION. CONCENTRATED: INCINERATION W/ALKALINE SCRUBBER.
385	SODIUM CHLORATE	NO	—	7 (p.84)	REDUCTION; INCINERATION W/SCRUBBER
430	THALLIUM	NO	—	8 (p.125)	PRESENT METHOD ADEQUATE: STOCKPILING OF ZINC DROSS CONTAINING TRACE QTIES. OF THALLIUM; PRODUCTION OF THALLIUM FROM STOCKPILED ZINC DROSS
431	THALLIUM SULFATE	NO	—	8 (p.125)	PRESENT METHOD ADEQUATE STOCKPILING OF ZINC DROSS CONTAINING TRACE QTIES. OF THALLIUM; PRODUCTION OF THALLIUM FROM STOCKPILED ZINC DROSS
122	COPPER SULFATE	NO	7	9 (p.137)	RECOVERY, PRECIPITATION/LANDFILL

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NUCLEAR HAZARDOUS WASTE

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MAT'L NO	H.W. MATERIAL	NATIONAL CANDIDATE		ACTUAL COMPLETION DATE	RECOMMENDED* TREATMENT
	CESIUM-134	YES		7 (p 263)	LOW LEVEL: RECOVERY/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	CESIUM-137 (BARIUM-137)	YES		7 (p 263)	LOW LEVEL: RECOVERY/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGES; SPRAY SOLIDIFICATION/SALT BEDS
	PLUTONIUM-238	YES		7 (p 293)	(RECOVERY OF UP TO 99.8% BY SOLVENT EXTRACTION PROCESS. REMAINING .2%: SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	PLUTONIUM-239	YES		7 (p 293)	(RECOVERY OF UP TO 99.8% BY SOLVENT EXTRACTION PROCESS. REMAINING .2%: SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	PLUTONIUM-240	YES		7 (p 293)	(RECOVERY OF UP TO 99.8% BY SOLVENT EXTRACTION PROCESS. REMAINING .2%: SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	PLUTONIUM-241	YES		7 (p 293)	(RECOVERY OF UP TO 99.8% BY SOLVENT EXTRACTION PROCESS. REMAINING .2%: SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	AMERICIUM-241	YES		7 (p 293)	SPRAY SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	AMERICIUM-243	YES		7 (p 293)	SPRAY SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	CURIUM-242	YES		7 (p 293)	SPRAY SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	CURIUM-244	YES		7 (p 293)	SPRAY SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	RUTHENIUM-106 (RHODIUM-106)	YES		7 (p 325)	LOW LEVEL: RECOVERY/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE. SPRAY SOLIDIFICATION/SALT BEDS
	CERIUM-144 (PRASEODYMIUM-[illegible])	YES		7 (p 325)	LOW LEVEL: RECOVERY/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	PROMETHIUM-147	YES		7 (p 325)	LOW LEVEL: RECOVERY/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	STRONTIUM-90 (YTTRIUM-90)	YES		7 (p 351)	LOW LEVEL: RECOVERY (SCAVENGING-PRECIPITATION ION EXCHANGE)/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	ZIRCONIUM-95	YES		7 (p 375)	LOW LEVEL: RECOVERY (SCAVENGING-PRECIPITATION ION EXCHANGE)/SOLIDIFICATION W/ASPHALT/LANDFILL HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	NIOBIUM-95	YES		7 (p 375)	LOW LEVEL: RECOVERY (SCAVENGING-PRECIPITATION ION EXCHANGE)/SOLIDIFICATION W/ASPHALT/LANDFILL HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	CARBON-14	YES		8 (p 229)	SOLIDIFICATION W/ASPHALT, IF REQUIRED/LANDFILL
	COBALT-60	YES		8 (p 229)	SOLIDIFICATION W/ASPHALT, IF REQUIRED/LANDFILL
	IRIDIUM-192	YES		8 (p 229)	SOLIDIFICATION W/ASPHALT, IF REQUIRED/LANDFILL

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NUCLEAR HAZARDOUS WASTE

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PART. NO.	H. W. MATERIAL	NATIONAL CANDIDATE		ACTUAL COMPLETION DATE	RECOMMENDED * TREATMENT
	RADIUM-226	YES		8 (p.229)	NEAR-SURFACE SOLID STORAGE/SALT BEDS
	IODINE-129	YES		8 (p.251)	RECOVERY USING SILVER ZEOLITE/NEAR-SURFACE SOLID STORAGE/SALT BEDS
	IODINE-131	YES		8 (p.251)	RECOVERY USING SILVER ZEOLITE/NEAR-SURFACE SOLID STORAGE/SALT BEDS
	KRYPTON-85	YES		8 (p.251)	RECOVERY USING FLUOROCARBON SOLVENTS OR CRYOGENIC DISTILLATION/NEAR-SURFACE SOLID STORAGE/SALT BEDS
	XENON-133	YES		8 (p.251)	RECOVERY USING FLUOROCARBON SOLVENTS OR CRYOGENIC DISTILLATION/NEAR-SURFACE SOLID STORAGE/SALT BEDS
	H^3-TRITIUM	YES		9 (p.275)	RECOVERY USING VOL OXIDATION PROCESS OR EQUIVALENT/NEAR-SURFACE LIQUID STORAGE/SALT BEDS

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